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NOTICES.

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Issue of Journal. The Journal is published in six bi-monthly parts per volume, viz., February, April, June, August, October and December. A brochure giving the History, Regulations and List of Members of the Institution was published in January, 1923, and the revised List of Members will be published periodically.

All members receive these publications free of cost. Additional copies of the Journal are charged at the rate of 7s. 6d. per part, unless otherwise stated, and of any other publication at the price stated on the wrapper.

Changes of Address. Members are requested to notify any change of address to the Secretary, and also to advise the Parcel Post Department and the Letter Office in order that correspondence may be re-addressed.

Papers and Articles. Papers and articles should be written in the third person, and drawings, diagrams, etc., illustrating a subject should be suitable for direct photographic reproduction.

English equivalents of foreign weights and measures should be given, and it is suggested that a bibliography of the subject dealt with be appended.

All papers and articles submitted are assumed to be original communications unless otherwise stated, in which case reference to the previous publication should be given.

Members are invited to submit papers to be read at the General Meetings of the Institution, and are specially asked to forward articles for publication in the Journal.

Members desiring to receive advance galley proofs of papers to be read before the Institution should apply to the Secretary, informing him of the address to which the proof is to be sent.

Binding of Journals. Cases for binding the Journal can be obtained from Messrs. W. Speaight and Sons, Limited, 98, Fetter Lane, London, E.C. 4, at a cost of 1s. 6d. post free, remittance to accompany order.

Members desiring to have their Journals bound in these cases should send their Journals, together with an additional remittance of 3s. per volume, to Messrs. Speaight and Sons, Ltd.

This notice applies to all previous volumes.

Reprints of Papers. Authors of papers published in the Journal are entitled to 25 free reprints of their contribution, and may obtain further copies at the following rates per 25 copies :—

2 pp., **2s. 0d.**	12 pp., **7s. 6d.**
4 pp., **3s. 0d.**	16 pp., **10s. 0d.**
8 pp., **5s. 0d.**	20 pp., **12s. 6d.**

Orders for extra reprints should be sent to the printers when the manuscript is forwarded to the editor.

Bibliography and Abstracts. A bibliography of current literature is published with each issue of the Journal, together with abstracts of the more important articles and patent specifications, this supplement being paged separately to the Transactions. In order to make this section of the maximum value, members are requested to send any matter which may have been inadvertently overlooked to the editor.

Medal for Student Members. A medal and a prize of five guineas will be awarded annually by the Council to that Student Member of the Institution who shall, in their opinion, have presented a paper of outstanding merit during the year.

Advertisements. A number of Advertisements are inserted in the Journal, and information as to terms, etc., can be obtained from The Advertisement Manager, Journal of the Institution of Petroleum Technologists, Aldine House, Bedford Street, Strand, London, W.C. 2.

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Appointments Register. A register of members requiring appointments is kept at the office of the Institution for the convenience of firms requiring the services of petroleum technologists, etc., it being understood that the Institution accepts no responsibility and gives no guarantee.

Library. The Institution's Library may be consulted between the hours of 11 a.m. and 4 p.m. daily. The additions made to the current and standard literature on petroleum and allied substances, since the publication of the last Journal, are :—

Report on the Investigation of the Russian Imperial Geological Committee, 1912. Translated from the Russian by F. E. Cherry.

The Recent Search for Oil in Great Britain. By H. P. W. Giffard.

The Oil Horizons of England. By C. E. N. Bromehead.

From the Institution of Mechanical Engineers :—

Proceedings, Vol. I, Jan.-April, 1923.

From the Geological Survey of India :—

Part III., Vol. LIV., and Part I., Vol. LV.

From the Geological Society of Glasgow :—

Part I., Vol. XVII., 1919-1922.

***

From the Publishers (for review) :—

The Examination of Petroleum. By W. A. Hamor and F. W. Padgett.

Redwood and Eastlake's Petroleum Technologists Pocket Book. 2nd ed. Revised by Arthur W. Eastlake.

Petroleum Resources of the World. By Valentin R. Garfias.

From Mr. F. G. Rappoport :—

Geological Report on the Districts of Payap and Maharashtra, Northern Siam. By Wallace Lee.

From the Imperial College of Science and Technology :—

Calendar for Session 1923–24.

From the University of Birmingham :—

Regulations and Syllabus, 1923–24.

From the Sir John Cass Technical Institute :—

Syllabus of Classes, Session 1923–24.

From the Imperial Mineral Resources Bureau :—

The Mineral Industry of the British Empire and Foreign Countries. War Period. Gypsum. 1913–1919.

From the Mellon Institute, U.S.A. :—

List of Books, etc., for 1923.

From the Diesel Engine Users' Association :—

Losses in Heat Engines and Means of Reducing Them. By Engr.-Comdr. W. P. Sillince, R.N. With report of discussion.

From the Department of Mines, Canada :—

Silica in Canada. By L. Heber Cole.

From the American Society for Testing Materials :—

A.S.T.M. Standards adopted in 1923.

A.S.T.M. Year Book, August, 1923.

A.S.T.M. 1923 Report of Committee D-2 on Petroleum Products and Lubricants.

From the Department of the Interior, U.S. Geological Survey :—

Bulletin No. 717. Sodium Sulphate. Its Sources and Uses. By Roger C. Wells.

Bulletin No. 718. Geology and Ore Deposits of the Creede District, Colorado. By W. H. Emmons and Esper S. Larsen.

Bulletin No. 738. The Commercial Granites of New England. By T. Nelson Dale.

Bulletin No. 745. The Kotsina-Kuskulana District, Alaska. By F. H. Moffit and J. B. Mertie, Junr.

Bulletin No. 750. A. Ilsemannite at Ouray, Utah. By Frank L. Hess.

Water-Supply Paper No. 469. Surface Waters of Wyoming and their Utilisation. By R. Follansbee.

Water-Supply Paper No. 495. Geology and Ground-water resources of Sacramento Valley, California. By Kirk Bryan.

Water-Supply Paper No. 496. The Industrial Utility of Public Water Supplies in the United States. By W. D. Collins.

Mineral Resources of the United States. Part I., 1920.

Coke and By-Products in 1921. By R. S. McBride.

Peat in 1922. By K. W. Cottrell.

The Council would be grateful to members who are authors of books on petroleum or on allied substances, if they would kindly present a copy of their works to the Library of the Institution, and for review in the Journal.

PERSONAL NOTES OF MEMBERS AND SPECIAL NOTICES.

It is suggested that members send information regarding their movements to the Secretary, for insertion under this heading.

Mr. F. M. Penney is on his way to Angola, Portuguese West Africa.

Mr. C. P. Hale sailed for Lobitos, Peru, on August 27th.

Mr. J. R. Bourchier has returned from Persia.

Mr. R. K. Richardson is back from Persia.

Mr. G. E. Owles is on his way back to Lobitos, Peru.

Mr. F. G. Rappoport has now returned from his trip to Siam and Burma.

Mr. L. V. Boggs has returned from a trip through the oil-fields of Persia, India, Burma and Egypt, and sailed on September 15th for New York.

Mr. B. F. N. Macrorie has returned from Venezuela.

Lt.-Col. S. J. M. Auld is leaving for Persia shortly.

Mr. E. Parsons is proceeding to India in October.

MR. ALBERT MILLAR is returning to Galicia during the latter part of November.

The Secretary will be glad to receive information concerning the whereabouts of the following members: MR. WILLIAM TRAVIS ARNETT, MR. DOUGLAS LUTMAN HOUGHTON, and MR. ALBERT JEFFREYS.

It is gratifying to record that the inaugural meeting of the Session, held on October 9th, was attended by over 160 members and visitors, including the following Members of Council: Mr. H. Barringer (President), Sir F. W. Black, Prof. J. S. S. Brame, Messrs. E. H. Cunningham Craig, Ashley Carter, A. Duckham, Arthur W. Eastlake, T. C. Palmer, Rear-Admiral P. W. Dumas, Drs. A. E. Dunstan and W. R. Ormandy.

The "Report of the Committee of the Privy Council for Scientific and Industrial Research, for the year 1922–23," is now available, and can be obtained from H.M. Stationery Office, or through any bookseller, at the price of 4s. net, by post, 4s. 2d.

The classes in Petroleum Technology at the Sir John Cass Technical Institute commenced on September 24th. The lecturers, in the course on Oil Well and Refinery Technology and Geology of Petroleum, Part I., during the First Term are: A. E. Chambers, Ashley Carter, J. McConnell Sanders, Dr. W. R. Ormandy, Prof. J. S. S. Brame, and Dr. A. E. Dunstan.

The Inaugural Meeting of the Birmingham Branch of the Students' Section will take place at Birmingham on October 30th.

DISCUSSION ON PAPERS.

Those taking part in the discussion on papers read at the General Meetings of the Institution are requested to note that the official reporter's typescript sent to them for correction should be returned within seven days. Failing this, the report of their remarks as received from the reporter will be published subject to editorial corrections only.

THE "HOUSE WARMING" AT ALDINE HOUSE.

The "House-Warming" of the Institution's new offices at Aldine House on Wednesday evening, October 3rd, was attended by a

large number of members and their ladies, and was a great success. On arrival the guests were received by the President (Mr. H. Barringer) and Mrs. Barringer.

The President, in a short speech, declared the offices officially opened, and paid a tribute to the work of the Secretary and his staff in getting the rooms into their present orderly condition. He also referred to the newly-instituted Students' Section, and said that the Institution was looking forward to its doing a large amount of good work.

During the evening light refreshments were served, and a number of exhibits of apparatus used in the petroleum industry were on view, the various firms and their exhibits being :—

Townson & Mercer, Ltd	Chemical apparatus.
A. Gallenkamp & Co., Ltd.	Chemical apparatus.
Anglo-Persian Oil Co., Ltd.	Samples of petroleum products
C. C. Wakefield & Co., Ltd.	Hele-Shaw Streamline Filter.
Cambridge & Paul Instrument Co., Ltd.	Electrical apparatus.
A. Duckham & Co., Ltd.	Testing apparatus.
J. Orme & Co., Ltd.	Blown glassware for laboratories.
R. B. Grey	Grey Typhoon Agitator.
Empson Electrical Engineering Co., Ltd.	Dielectrimeter for testing insulating oils.
Tintometer, Ltd.	Lovibond Tintometer.
Baird & Tatlock, Ltd.	Testing apparatus.
Asiatic Petroleum Co., Ltd.	Testing apparatus.
Anglo-American Oil Co., Ltd.	Demulsification testing apparatus (A.S.T.M. method).
Shell-Mex, Ltd.	Testing apparatus.
Negretti & Zambra, Ltd.	Hydrometers, thermometers, etc.
W. Watson & Sons, Ltd.	Colour filter.

A special object of interest was the original Redwood Viscometer, which has been presented to the Institution by Mr. Robert Redwood.

The thanks of the Council are due to the Staff, for the excellent arrangements made for the occasion ; to the exhibitors, for kindly furnishing the scientific apparatus, etc., and to their representatives for their courtesy in demonstrating and explaining the exhibits.

STUDENTS' SECTION, LONDON BRANCH.

In the June issue of the Journal (No. 37) mention was made of meetings of Student Members of the Institution to discuss the formation of a Students' Section, and the names of those elected to serve on the Committee were published. Since then, this Committee has been engaged on work incidental to the formation of

the Section. At a meeting held at No. 5, John Street, on June 8th, Mr. H. G. Austin, the Honorary Secretary, was unanimously elected to the position of Chairman of the Committee, Mr. F. R. S. Henson being elected as Vice-Chairman.

Rules for the Section have been prepared, and these, as approved by the Council of the Institution, are given below.

Meetings of the Section will be held at Aldine House, commencing at 6 p.m., on the fourth Tuesday of each month from October to May inclusive, except in December, when the Meeting will be held on the 18th.

Three papers have been submitted to the Committee, and the Honorary Secretary will be pleased to hear from Student Members who have papers in course of preparation, in order that a full programme for the forthcoming Session may be arranged as soon as possible.

All members of the Institution will be welcome at the monthly meetings of the Section, and the Committee feel sure that their contributions to the discussion will prove of great interest and value to the Students present.

In addition, it is hoped to arrange several visits to works, refineries, and storage installations in London and the Home Counties during the winter, and the Honorary Secretary will much appreciate the assistance of any members of the Institution who may be able to help the Section in this matter.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

STUDENTS' SECTION.

RULES.

Rule 1.—The name of the Section shall be :—

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS, STUDENTS' SECTION, LONDON BRANCH.

Rule 2.—The Section shall be bound by the Articles of Association, By-Laws and Regulations of the Institution.

Rule 3.—All Student Members of the Institution are entitled to be Members of the Students' Section.

Rule 4.—No subscription shall be required other than that payable to the Institution under the By-Laws and Regulations.

Rule 5.—The expenditure incurred on behalf of the Section as authorised by the Council of the Institution shall be borne by the Committee of the Section out of the grants made by the Institution (see Rule 12).

Rule 6.—The objects of the Section shall be: To arrange meetings for the reading and discussion of papers, and for the informal discussion of subjects of interest; to arrange visits to various works and objects of engineering and scientific interest, and to promote a general feeling of good fellowship among the students.

Rule 7.—A Meeting shall ordinarily be held in each month from October to May, inclusive—the meetings to be occupied by the reading of papers, informal discussions, or as may be determined by the Committee of the Section.

Rule 8.—The Annual General Meeting of the Section shall be held in one of the first three months of every year, at least three weeks before the Annual General Meeting of the Institution.

Rule 9.—Every meeting of the Section shall be under the Chairmanship of the Chairman of the Section, or the Vice-Chairman, in the absence of the Chairman; in the absence of both the Chairman and Vice-Chairman, a member of the Committee shall be elected by the members present.

Rule 10.—A programme of all meetings, visits, etc., shall be arranged, as far as is practicable, by the Committee, before the commencement of each Session, so that it may be forwarded to every member of the Section before the Session commences.

Rule 11.—Members of the Section are entitled to the privilege of inviting a friend to any meeting of the Section. Only the Committee may invite guests to take part in a visit.

Members of the Institution, other than students, attending the meeting, shall not join in the discussion until the Chairman announces that the discussion is open to anyone present.

The Committee of the Section may invite Members of other kindred societies to attend any meeting, and to take part in the discussion.

Each Member of the Section and Visitor shall sign the Attendance Book before entering a meeting or when on a visit.

Rule 12.—The affairs of the Section shall be organised by a Committee consisting of not less than five nor more than eight members of the Section, who shall, subject to the Council of the Institution, manage the property and proceedings of the Section in accordance with these rules and the by-laws and regulations of the Institution from time to time in force.

Rule 13.—The election of the Committee shall take place at the Annual General Meeting of the Section, either by a show of hands or by ballot.

The Committee shall hold office for one year; at the end of their term of office the members of the Committee shall retire, and be eligible for re-election, providing they are still Student Members of the Institution.

Rule 14.—At the Ordinary Meeting of the Section preceding the Annual General Meeting of the Section, a number of members of the Section, sufficient for the membership of the Committee (see Rule 12), shall be nominated and seconded. No member of the Section shall nominate any person unless and until he has ascertained that the person so nominated is willing to serve. A list of those duly nominated and seconded shall be sent to each member of the Section.

Rule 15.—The Committee shall appoint annually from among themselves, a Chairman, Vice-Chairman and Honorary Secretary. The Chairman, Vice-Chairman and Honorary Secretary shall retire after holding office for one year, and shall be eligible for re-election, providing they are still Student Members of the Institution.

Rule 16.—The Committee of the Section may fill any casual vacancy in the Committee (including any casual vacancy in the office of Chairman, Vice-Chairman and Honorary Secretary), which shall occur between one Annual General Meeting and another, and the Chairman, Vice-Chairman or Honorary Secretary or Members of the Committee so appointed by the Committee shall retire at the succeeding Annual General Meeting.

Rule 17.—The election of the Chairman, Vice-Chairman and Honorary Secretary shall be made at the first Committee Meeting after the Annual General Meeting of the Section.

Rule 18.—The Committee may regulate their own procedure and delegate any of their powers and discretions to any one or more of their body, and may determine their own quorum. If no other number is prescribed, three members of the Committee shall form a quorum.

Rule 19.—The Chairman of the Section and the Honorary Secretary of the Section shall be *ex-officio* members of all Committees.

Rule 20.—The Chairman of the Meeting shall have a casting vote in cases of equality on any questions at any meeting of the Section or of the Committee.

Rule 21.—The Honorary Secretary shall conduct the correspondence in connection with the Section. He shall send to the Secretary of the Institution particulars of all meetings for inclusion in the records of the Institution, and shall issue to all members of the Section notices of all Section meetings, and take minutes of all business transacted thereat, and shall enter same in a minute book.

Rule 22.—Four clear days' notice of every Meeting, specifying generally the nature of any special business to be transacted at any meeting, shall be given to every person on the register of the Section, except as provided in Rule 23, and no other special business shall be transacted at such meeting, but the non-receipt of such notice shall not invalidate the proceedings of such meetings. No notice of the business to be transacted shall be required in the absence of special business.

Rule 23.—No Member of the Section not having a registered address within the Un ted Kingdom shall be entitled to any notice, and all proceedings may be had and taken without notice to such member in the same manner as if he had had due notice.

Rule 24.—A Special Meeting may be convened by the Committee of the Section at any time, and shall be convened by them when ever a requisition signed by at least 15 members of the Section, and stating the business of the Meeting, is forwarded to the Honorary Secretary. If for fourteen days after the delivery of such a requisition, a meeting shall not be convened in accordance therewith, the requisitionists, or any number of members of the Section exceeding 15 (fifteen), may convene the meeting.

All Special Meetings shall be held in London.

CURRENT PETROLEUM NOTES.

The receipt of notes of interest for insertion under this heading will be welcomed by the Editor.

PROTECTION FOR FLOWING WELLS.—The August issue of the *Mining and Oil Bulletin* contains an article describing a steel housing for the protection of flowing wells from fire. The housing is bolted to a circular concrete foundation, through the walls of which the flow lines pass. The steel shell is 9 feet in diameter, 6 feet in height, and surmounted by a cone 4 feet high, to the top of which an eye-bolt is secured to enable it to be lifted for repairs, etc. Two quick-opening manholes are fitted in the body of the shell for the ready adjustment and inspection of fittings.

RUSSIA.—The production of petroleum in Soviet Russia for the months of April, May and June, 1923, is reported as being 79,178,000 poods, a monthly average of 26,393,000 poods. This amount is made up by 56,238,000 poods from Baku, 20,883,000 poods from Grozni, and 2,057,000 poods from Emba.

SOUTH AFRICA.—The imports of petroleum and its products during 1922 were as follows :—

	Union of South Africa.	Northern Rhodesia.	Southern Rhodesia.	South-West Africa Protectorate.	Total.
	Imp. Gals.	Imp. Gals.	Imp. Gals.	Imp. Gals.	Imp. Gals.
Kerosene ..	9,210,026	30,859	233,156	199,912	9,673,953
Gasoline and naphthas ..	10,671,847	22,370	403,698	154,658	11,252,573
Lubricating oil	2,431,742	20,060	221,733	33,225	2,706,760
Other mineral oils (including fuel oil) ..	1,290,300	24	56,073	96,679	1,443,076
	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.
Paraffin and stearin wax	19,266,285	—	610,655	—	19,876,940
Antifriction grease ..	3,508,068	35,508	410,623	—	3,954,199
Tar and substitutes ..	—	10,416	—	74,296	74,296
Pitch	—		—	2,248	12,664
Asphalt and bitumen ..	—		—	510	510

NEW ZEALAND.—The quantities of petroleum and its products imported into New Zealand during 1922 were :—

Liquid Products.	Imperial Gallons.
Crude and partly refined	216,596
Residual oils	232,239
Benzine	2,722,255
Gasoline	852,125
Motor spirit	12,941,900
Naphtha	742
Benzolene	69,336
Kerosene	4,127,330
Lubricating oils	1,121,377
Other refined oils	6,572
Total liquid products	22,290,472

Solid Products.	Pounds.
Paraffin wax	3,936,770
Mineral greases	458,000
Candles	1,201,421
Asphalt	3,117,500
Total solid products	8,713,691

PETROLEUM RESEARCH AND REFINERY.

CHEMIST.—Shortly disengaged; 10 years' professional experience; 5 years' war service including 1 year Ministry of Munitions Research Staff; associated several years petroleum research on works scale; administrative and refinery control; accustomed control of labour; England or Rumania preferred.—Write, A.I.C., c.o., Institution of Petroleum Technologists.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

A Meeting of the Institution of Petroleum Technologists was held at the Royal Society of Arts, John Street, Adelphi, W.C., on Tuesday evening, 9th October, 1923, Mr. H. Barringer, M.Inst.C.E., M.I.Mech.E., M.I.N.A. (President), in the Chair.

The President, at the opening of the Meeting, cordially welcomed the members to the opening Meeting of the new Session, and **The Secretary** then read the list of seventy-six newly-elected members.

Members.—Paul Arbon, Louis Brown, Abner Faison Dixon, Leslie McGregor Fraser, Arthur D. Little, William Richard Macdonald, Alfred George Marshall, Albert Edison Miller, Christopher Howell McCarthy-Jones, Robert Smith McWhinnie, William Tempest Parez, Frederick Peel, Robert Pitkethly, Claude George Sara, Arthur D. Smith, Joseph Streda, Hein Iszael Waterman, and Branko Georges Yovanovitch.

Associate Members.—Thomas C. Bannon, William Drummond Bayne, Thomas Edgar Beaumont, Charles Edward Douglas, Humphrey William Gilbert Duthy, Smith Austin Guest, Albert Chittenden Isom, Sidney Leonard Mainprize, Edward Charles Masterson, Ebenezer Simpson Millar, George Urquhart Morgan, Xavier Normand and George Woodman.

Transference from Student.—Mostafa Allam and Geoffrey Chambers Flower.

Students.—John Horace Blakiston, Eric Herrmann Booth, Henry Charles Carter, Ernest Clark, Geoffrey Cotton, Galfrid Clement Keyworth Dunsterville, Arthur Victor Easty, Gwyn Elias, Oswald Fosbrooke, Thomas Clifford Glanville, Trayan V. E. Grigorescu, Richard Eldred Gubbins, Henry LeMarchant Stevens Guille, Dudley Harry Gwinner, Aubrey George Goodrich Hanks, William Ardagh Harrop Harrison, William Ross Sutherland Henderson, Ernest Douglas Irving, Nicholas Merab Kvitashvili, Eugene Leovovitch Leites, Norman Longbottom, Herbert Richard Lovely, Ian Campbell Low, Constantin C. Manciulescu, Charles Alexander Moon, Alfred Nutsford, Philip Emmet Taaffe O'Connor, Alfred Paul Barrow Paget, James Harris Park, Eustace William Howard Peel, Charles Alec Picton, Harold Wallace Reid, Charles

Alan Sansom, Wladimir Schlusser, George Francis Wallis, Christopher John Ward, Leslie Newton White, Cedric Clark Wilson, Geoffrey Wilson, Yvor Patten Wilson and Eric Blachford Woodrow.

Associates.—Alfred George Lewys Owen and Ronald Sowerby Teale.

The following paper was then read :—

Recent Researches Bearing Upon the Origin of Petroleum.

By E. H. Cunningham-Craig, B.A., F.R.S.E., F.G.S. (Member).

For a long time it has been considered by the Council of this Institution, and by many of the members, that a comprehensive discussion upon the intensely interesting subject of the Origin of Petroleum would be welcomed, not only to enable the views of all those who have conducted original investigations to be put forward, but to help to crystallise the ideas of technologists, and, if possible, to enable some definite pronouncement to be made upon a question of vital importance.

The position which this Institution has achieved in the oil world makes it all the more important that a lead should be given to those engaged in research work in a scientific question which has been so often debated.

The subject has been a fruitful source of discussion and even controversy, but of late years, by what seems to be general consent, there has been a cessation of polemics, and writers on the subject have been content to give bald, and not always accurate, statements of theories put forward, without leaning to one side or the other upon controversial points.

Now, in opening this discussion it is not proposed to consider the subject generally, nor to recount once more the well-known arguments which have been so often published. It is hoped that it will suffice to deal with some of the researches which have been undertaken in recent years, researches which have a distinct bearing, direct or indirect, upon the question of the origin of petroleum.

The genesis of petroleum has been variously attributed to :—

A. Inorganic Origin : { (1) Hypogene causes. (2) Vulcanicity.

B. Organic Origin : { (1) From animal matter. (2) From vegetable matter.

A. (1).—Of the hypogene origin there is little to be said. It is suggested that the action of water upon supposititious metallic carbides beneath the outer crust of the earth may have formed hydrocarbons, which might eventually condense into the complicated mixture of these bodies known as crude oil. This theory is obviously merely a speculative idea, and is not seriously considered nowadays.

(2) A somewhat vague theory of the volcanic origin of oil has been suggested, but not very definitely stated. The geological evidence advanced in favour of it is open to at least two mutually contradictory interpretations, and the theory has not found acceptance among scientific observers.

This leaves the organic theories as rivals, that of animal origin being chiefly supported by chemists, while the vegetable origin theory is largely held by geologists, and has gained much ground in recent years among practical field-workers.

Without entering into the time-honoured arguments that have been mooted and discussed from time to time, published, refuted, republished and disputed over, let it suffice to call attention to some of the recent work that throws light upon the vegetable origin theory.

There is a growing tendency at the present time to conduct researches upon the question of the relations of coals and lignites to petroleum. Every country that contains either coal or petroleum, or both, can furnish some evidence, and it is becoming obvious to geologists that the two fuels have definite relations to each other.

It has been pointed out by the writer that the three main oil-bearing horizons in Trinidad have each a carbonaceous phase in some other district, and that the two phases, petroliferous and carbonaceous, approach each other very closely in some localities.

Similar evidence has been forthcoming from many countries, *e.g.*, Venezuela, Burma, Assam, Hungary and Rumania. In Assam a coal-bearing series succeeds an oil-bearing series, but the two overlap to some extent, so that oil and coal alternate throughout a zone of appreciable thickness, oil increasing in the lower strata and coal in the upper. In Hungary, owing to careful stratigraphical work, it has been proved that oil-bearing horizons in one district are equivalent to lignitic strata in another, in a different environment.

In Rumania even more striking evidence is forthcoming, as the result of further knowledge of the stratigraphy: the main oilfields are proved to lie within the areas of great Tertiary deltas, and lignitic beds in one quarter are proved to be represented by an oil-bearing formation in another. Furthermore, the writer has detected the well-known transition stage marked by extensive porcellanite outcrops.

Much pertinent evidence from Great Britain was also brought to light by the work of the Petroleum Research Department during the War, but unpublished, and the relations of oil to coal and to oil-shale have been made clearer. Perhaps the most striking evidence is that afforded by the boring at D'Arcy, near Dalkeith. This well was drilled on the theory that oil-shale denotes petroleum that is dead and buried, but that beneath an oil-shale series some free petroleum may still exist. This view was combated hotly at one time, but the drill put the question out of the realm of controversy, for not only was true free petroleum (though in small quantity) encountered, where there are no igneous rocks to distil a cracked petroleum from shales, but the two principal shows of oil were met with within ten feet of the depths predicted, *viz.*, at 1490 and 1810 feet. The predicted depths were 1500 and 1800 feet, respectively. These matters, however, are of more general than particular interest.

The next point to be mentioned is the research work that has been done upon the hydrogenation of coal. By treating any coal containing a fair percentage of volatile matter with hydrogen under very high pressure and at temperatures up to 850° F., a remarkable exothermic action is induced and a portion of the solid fuel becomes liquefied, giving as a result a product indistinguishable from heavy crude petroleum. Similar effects can be obtained by hydrogenating heavy crude oils, lighter oils being formed. The work of Dr. Bergius, though perhaps hardly yet successful as a commercial proposition when coal is treated, or, as it is stated, "liquefied," has certainly opened up a vista of great possibilities. It appears that the percentage of volatile matter in the coal is one of the determining factors controlling the reaction, another being the pressure. Pressures as high as 3000 and even 5000 lbs. per square inch have been used, but action may commence with a pressure of no more than 600 lbs. Temperatures need not apparently be very high, but as the action is exothermic there is difficulty in keeping it from rising too high. The reaction takes place in an autoclave.

The value and importance of these researches of Dr. Bergius lie in the attempt to reproduce conditions similar to those that must have occurred in Nature during the formation of oil. It has long been recognised that coal is a finished product, and that oils cannot be formed from it except by distillation. The carbon-hydrogen ratio in coal is too high, though it varies, of course, in different coals. Therefore, in treating a coal to make oil, hydrogen must be supplied. This Dr. Bergius has done successfully, and the result is stated to be "almost identical with crude petroleum, and which in the same way can be separated by fractionation into an enormous range of different chemical compounds."

But before the vegetable matter has reached the coal stage it is still sufficiently rich in hydrogen, or, to put it more clearly, the carbon-hydrogen ratio has not risen too far. Therefore, in an autoclave under sufficient pressure and at not too high a temperature we should expect petroleum to be formed from vegetable matter that has not reached the coal stage. The writer, in a rough calculation made some years ago, estimated that a minimum pressure of as much as 135 atmospheres might be necessary, and that in any case 189 atmospheres would be sufficient. Dr. Bergius has shown that 200 atmospheres is sufficient, though action may begin at as low as 40 atmospheres.

It would be interesting if some supporter of the animal theory would conduct the same hydrogenation experiments with deposits containing, or supposed to contain, animal matter, to learn whether liquids indistinguishable from petroleum can be formed from them. The difficulty might be in finding deposits rich enough in animal matter, but there must have been such deposits *if there be any truth in the animal origin theory*. A shell-bed, a fish-bed, a coral limestone, or a foraminiferal marl, each of which has been claimed at one time or another as a probable parent rock of petroleum, might be experimented with, but it is doubtful if such deposits would give such definite results as accumulations of vegetable matter.

The fact that the reaction is exothermic must not be lost sight of. External heating of the autoclave will retard the action, and the heat engendered by the action may be sufficient to check it and bring about an equilibrium. But in Nature, working slowly through countless periods of time, the rapid heating up of the material by an exothermic reaction will be obviated by conduction.

Should the temperature rise sufficiently to check the action, an increase of pressure will start it again till another equilibrium is attained. And so the process may be practically continuous over a lengthy period, with this difference, that a different range of products will be formed under each different condition of temperature and pressure. Thus different classes of crude petroleum may be formed from the same raw material according to the varying conditions of temperature and pressure. The stage of alteration of the vegetable matter must, however, have some effect upon the final result.

This leads us naturally to a consideration of the different types of vegetable deposit that are known, and their relative stages of alteration and carbonisation. Between peat and anthracite there is every gradation of deposit of vegetable origin, and it has been proved conclusively that the purest, those freest from inorganic contents, attain the coal stage earliest. Those which yield most oils on distillation are the cannels, which are impure deposits containing much inorganic matter in a very finely divided state. In

such beds the stage of carbonisation is found to be low, *i.e.*, much of the vegetable matter is still in a " jetonised " condition, of brown or red-brown colour, rather than the black characteristic of coals. Many carboniferous cannels seem quite lignitic when examined under the microscope, and they naturally have a very high percentage of volatile matter compared with normal coals in the same series.

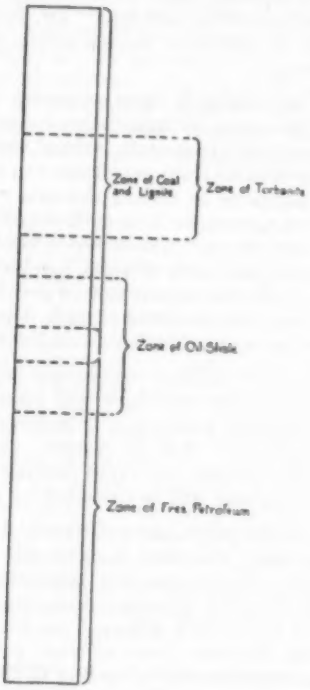


FIG. 1.

Consequently we should expect cannels to afford evidence bearing upon the formation of petroleum. And this is where the remarkable evidence of the Torbanites comes in to add another link to the chain.

In a former communication to this Institution the writer gave a brief account of his first researches upon this phase of petroleum, showing that the former theories of Bertrand, Renault and Jeffrey,

who claimed the gels as vegetable fossils, were untenable, as they were not solid bodies when the deposits were formed, but have developed across the lamination without disturbing it.

Since that former paper was read a great deal of further research has been undertaken, especially during the War, and a very large number of torbanitic deposits have been discovered in Britain and British Dominions. Usually microscopic examination is required to detect a torbanite except by those who are familiar with them, a fact that serves to excuse the statements of certain high officials to the effect that there were no deposits of this nature other than the old worked-out Torbane-hill mineral in Britain. The relations of torbanites to coals, oilshales, and free petroleum are shown diagrammatically in the vertical section, Fig. 1. A torbanite is merely a cannel containing sufficient colloidal inorganic matter, which has been subjected to the necessary pressure under adequate sealing—*i.e.*, in a natural autoclave.

In such conditions the oil begins to form in minute globules, which combine at once to form gels with the colloidal inorganic matter. Were the deposit entirely uncarbonised, or in a really early stage of carbonisation, it might be entirely converted into petroleum, which would impregnate the nearest porous strata, and leaving only the inorganic content; but it is evident from the coaly matrix in which the globules or gels are set, and also from the fact that coal seams are invariably associated, or in contact, with torbanite seams, that the process of carbonisation had at least been begun, and therefore the formation of oil globules is restricted. In some cases the microscope shows that only 10 per cent. or 15 per cent. of the deposit is formed of gels, in others the percentage may be as high as 80 or 90.

The deterioration of the gels by inspissation, and finally by resolution into organic and inorganic matter, has been studied and described, and the effect of high temperature on them has been the subject of experiment.

At a temperature of 250° C. the lighter oils begin to be driven off, and complete distillation takes place between 350° and 400° C., thus proving that they cannot have been formed at high temperatures.

The latest, and perhaps most important, research upon torbanite is that conducted by Professor A. E. Flynn, of Nova Scotia, who has separated the gels from the matrix by crushing a Nova Scotia torbanite and floating the gels in brine, so that they can be examined and analysed apart from the matrix. Professor Flynn finds that the gels are tough rather than hard, and so resist crushing successfully. A specimen of these separated gels shows that they are of

large size and rough exterior, like miniature almonds or walnuts; they are remarkably fresh and free from signs of inspissation. Analysed they are proved to contain from 16 to 20 per cent. of inorganic matter, the average content being rather more than 18. This inorganic matter, as was to be expected, is in a fine colloidal state and cannot be observed by the ordinary powers of a microscope. The inorganic content is quite conclusive proof that these gels are not vegetable fossils. This evidence, brought forward by Professor Flynn, confirms in every detail the views advanced by the writer in 1915, and subsequent years, and we may say that if oil-shale denotes petroleum "dead and buried," torbanite denotes petroleum "still-born."

A very rich and fresh torbanite such as is found in New South Wales would probably be entirely liquefied if subjected to Dr. Bergius' hydrogenation process, but the temperature would require to be kept comparatively low.

Now that these interesting deposits have been so fully studied their true significance can be appreciated: they show a stage in the formation of oil from vegetable deposits, checked and arrested owing to the particular environment in each case. There is no necessity for inventing such terms as "sapropel" and "sapropelic deposits"; the evidence is complete, and is as clear a case of the origin of oil from vegetable matter as can be desired.

The paper was illustrated by a number of microscopic slides of torbanites and allied deposits, which were shown by means of an optical lantern.

DISCUSSION.

Mr. A. W. Nash, in a written communication (read by **The Secretary**), said the author was to be congratulated on having introduced a subject for discussion in which everyone connected with the oil industry was interested.

The theory that petroleum was derived from organic matter by a process of natural distillation under dynamic and geothermic influence is one which was increasing in favour amongst many practical oil geologists and fields engineers to-day.

Nevertheless, the organic theory, whether animal or vegetable matter, was referred to was a long way from proven. The possible reason why this theory was upheld by so many was that, difficult enough as it was to prove it right, it was even more difficult to disprove it entirely.

In the case of animal matter, the question of disposing of the phosphorus contained in the remains entered into the consideration, as no phosphorus is found in petroleum: nevertheless we are told that W. C. Day obtained a residue like mineral pitch by distilling herrings; and that Warren and Storer obtained from fish oil, by distillation, members of the methane, ethylene, and benzene groups such as are found in petroleum.

He (Mr. Nash) would mention as a matter of passing interest, but not in support of the theory, that he obtained several pieces of shale, showing the imprint of fish remains, from beds immediately overlying the oil sands whilst drilling in the Maikop field.

The theory that petroleum and coal bear a close relationship to each other, as mentioned by the author, and so ably put forward in his works, had much to be said in its favour. Pictet and Bouvier explain how they obtained some of the same hydrocarbons as are to be found in petroleum by distilling coal. Methane gas is given off by both coal and petroleum, but in no instance had these substances been found in the same stratum, although it had been said by expert geologists that coal had been found in what they thought might be a continuation of an existing oil-bearing bed. Also, at the Government Geological Station in Poland carbonised plant remains found in the petroliferous regions of Galicia are to be seen. E. H. Pascoe stated that the Miocene beds of Burma, which was the producing formation of the Burma oilfields, contain coal fragments, but most of the primary oil beds of America and elsewhere are situated some considerable geological distance from the coal seams, consequently it would appear impossible to state definitely that the materials which had formed coal deposits are the same as those used by nature to form petroleum. Another fact worth bearing in mind was that although we had large coal deposits in this country, very little free oil had been found so far; in any case it has not adopted the usual method of making its presence known.

The author's reference to the experiments carried out by Dr. Friedrich Bergius of Heidelburg, is a most important one, and although the results do not necessarily settle the question now being dealt with, they certainly have opened up a wide field for research in that direction. Dr. Bergius's first experiments were carried out with the idea of imitating the geological process of the formation of coal. Wood fibre in contact with water was raised to a temperature of 340° C. under a pressure of 200 atmospheres, the result being a black powder similar in appearance and behaviour to coal. This product was then hydrogenated under a pressure of 100 atmospheres, and a temperature of 400° C., giving a black, viscous oil "similar to petroleum." If we are to accept this as representing the natural method of oil formation, then two questions at once arise, *viz.* :—

(1) Whence is obtained sufficient hydrogen for the second stage, and

(2) Why are ammonia, phenols, etc., never found in petroleum. They certainly exist in Dr. Bergius's liquid coal.

To produce petroleum from coal we must either introduce hydrogen into the substance or take carbon out. Now, when natural coal is hydrogenated large volumes of methane are liberated, which must account for the greater portion, if not all, of the hydrogen introduced. This being the case carbon is given up, leaving a residue with a higher hydrogen content in consequence. Experiments in the production of oil from coal have been carried out by the Research Section of the Oil Mining Department at the Birmingham University for some time past, with a certain amount of success. A sample of the product obtained, containing ammonia and phenols, is being sent under separate cover as likely to prove of interest to members. These experiments now being carried out by the Birmingham University are additional steps towards proving or disproving the theory that petroleum and coal have originated from the same material, and the work that has yet to be done will be very prolonged and laborious, as the following remarks will indicate. To imitate nature successfully, the raw materials must be obtained as, and how used, in nature: there are so many potential raw materials, however, both animal and vegetable, differing in constitution owing to decay, bacterial action, etc., that the magnitude of the work is not at first sight appreciated by those not concerned.

Mr. Cunningham Craig suggests hydrogenating animal remains. Assuming for the moment that these remains are the source of petroleum; how are we to know at which stage of their decomposition or decay they are acted upon by hydrogen to give petroleum. The same remarks apply, of course, to vegetable matter.

Before leaving the subject a reference to the inorganic theory might not be out of place. According to W. Ramsay it has been shown that carbon, carbon monoxide, and carbon dioxide, can be hydrogenated in the presence of a nickel catalyst to form methane at comparatively low pressures and temperatures, while at higher temperatures and pressures, higher hydrocarbons are formed. We know that hydrogen and carbon dioxide occur as natural gas in the earth: also that the ash of many crude oils is composed largely of nickel. From experiments carried out on a number of crudes, Ramsay established the fact that hydrocarbons of the paraffin series carried more nickel than those containing large quantities of unsaturated hydrocarbons. He assumed, therefore, that the degree of hydrogenation was governed by the amount of nickel present. He (Mr. Nash) was of opinion that this theory cannot be disproved by any known geological fact.

The hydrogenation of heavy oils to obtain lighter products has been touched on by the author, and it might not be out of place to amplify his remark somewhat. The Bergius patent covers, not only the use of hydrogen, but also nitrogen and carbon dioxide. Gas oils have been "cracked" at the Birmingham University laboratories by the so-called hydrogenation process, yielding 50 per cent. of petrol with a particularly sweet smell, and fairly free from unsaturated compounds. The question that at once arises is whether the hydrogen was absorbed by the oil, or whether it simply aids the exothermic action to obtain a higher final pressure. If the latter then the experiment becomes one of ordinary "cracking" under a very high pressure and temperature, and nitrogenation would be just as effective.

Perhaps someone with more experience in this direction might be able to enlighten members on this point.

The President was sure the members were greatly indebted to the author for his very interesting paper, and the beautiful slides with which it had been illustrated. The members knew the author so well that naturally any opinion he put forward must carry the very greatest weight, and personally he must say, after hearing the paper, that the author seemed to have made out a very good case for the vegetable origin. Dr. Bergius's experiments seemed to go as far as it was possible in that direction to prove his theory. Probably and possibly there might be a certain amount of animal deposit entangled in the vegetable deposit; but whether they contributed to the production of petroleum, or whether they added to the impurities which gave so much trouble it was impossible to say. He was looking forward to a very interesting discussion on the part of those who were better able to criticise the paper than he was, and he hoped it would be found that some of the opposite school who were present who would be able to combat some of the author's theories.

Mr. T. Dewhurst said a friend of his informed him a short time ago that he had been studying petroleum geology, and had reached the conclusion that it was not a science, but an example of impure empiricism. Apart from the adjective impure, there was something in the criticism, as petroleum geologists needed to discuss and form sound conclusions regarding the main general questions of petroleum geology, such as the origin, migration and accumulation of petroleum. The serious manner in which some writers discussed the "emanation" theory, the "carbide" theory, the "volcanic" theory, and in regard to structure the "anticlinal" theory, sometimes suggested that petroleum geology had not yet passed the "phlogiston" stage. Petroleum had an extensive geographical

distribution and a wide geological range. All the big commercial accumulations of petroleum occurred in sedimentary rocks. Apart from the migration of oil along faults, and along planes of unconformability and overlap, it might be taken for granted that petroleum was indigenous to the rocks in which it was found, and that it was formed from the organic matter which was deposited in the sediments which ultimately formed the oil measures. Petroleum geologists owed a debt of gratitude to the author for his insistence on the importance of the Origin of Petroleum, and for his determined insistence on the claims of terrestrial vegetation to the parentage of petroleum. They only needed a protagonist of equal standing, who was convinced that all the oil in the world was formed from animal matter. With regard to the origin of oil from terrestrial vegetation, in Upper Assam there was a very close association of petroleum and lignite. All the productive oil-sands occurred just above the lignite seams. This was not in accordance with the diagram shown by the author. However, an oil-sand occurred just beneath, and in contact with, a seam of coal. On the Arakan Coast there was also close association of petroleum and lignite. From Mr. Kewley's paper on "The Crude Oils of Borneo,"* it was obvious that there was a close association of oil and coal in that country. With regard to the Mid-Continent Fields, Dr. Bosworth, in his "Geology of the Mid-Continent Fields," ascribed a vegetable origin to the oil, and stated that "Coal seams are present at intervals throughout a great part of the oil-bearing formations, and much of the clay-shale and sandstone contains abundant carbonaceous particles derived from plants." Emmons gave instances of the association of oil and coal, and although he pointed out that "The great coal-producing strata of the earth are not the oil-producing strata," he stated that "Many of the oil-producing strata are nevertheless lignitic or closely associated with highly lignitic beds—more generally in Europe and Asia than in North America." Some time ago he (the speaker) visited an interesting mine at Tataros, close to the present border of Hungary and Rumania. A lignite bed, 1½ to 2 feet thick, was exposed, and lying immediately above, and in contact with, the lignite was a bed of asphalt sand about 6 feet thick. There the oil-sand occurred immediately above the lignite, and the section did not agree with the diagram shown by the author. There was a good deal of evidence to show that petroleum and lignite were very closely associated in a large number of oilfields. It seemed to be highly probable that the oil in certain oilfields was formed largely from the remains of terrestrial vegetation. However, one of the interesting features concerning the origin of oil was that the conclusions which seemed to be indicated by the evidence in one field, or a certain number of fields, was

* *Journ. Inst. Petr. Techn.*, vii., pp. 209-233. 1921.

flatly contradicted by the evidence from other fields. In the Punjab, apparently no coal or lignite was associated with the oil or with the oil-measures. Mr. Pinfold, in his paper on "The Conditions Governing the Occurrence of Oil in the Punjab," stated that "Neither the massive nummulitic limestones nor the nummulitic shales contain original oil, and it is improbable that nummulitics contributed in any way to the formation of the oil. It seemed probable that the oil was derived from the decomposition of soft-bodied organisms, possibly seaweeds." The petroleum in Persia was apparently not associated in any way with coal or lignite. The nearest coal or lignite was situated hundreds of miles from the oilfields. It was interesting to study the geological age of petroleum in relation to its origin. In the United States the Ordovician and the Devonian were among the principal producing geological systems. The Middle Ordovician Trenton Limestone was productive in half-a-dozen States. The High Bridge Limestone formation underlay the Trenton proper, and yielded some production in Barren, Clinton, and Cumberland Counties. Small seepages of oil and good showings of natural gas had been found in the Knox Dolomite, which occurred below the High Bridge formation, and which was sometimes referred to as the "Cambro-Ordovician" system. Day stated that the Cambrian Potsdam Sandstone was productive in New York and Ontario, and that the Cambrian Quebec group was also productive. Cambrian production was, however, small and unimportant. Oil also occurred in Ordovician rocks in Newfoundland, and in Lower Silurian rocks in Sweden and in a narrow belt south of the Gulf of Finland. The first indubitable evidences of terrestrial vegetation occurred in Upper Silurian rocks. The known land plants of Silurian time were exceedingly few, and the specimens were rather indistinct. A few ferns and *Lepidodendra* had been recognised in Lower Devonian rocks. However, terrestrial vegetation became firmly established in Devonian times, and in agreement with that conclusion the earliest known coals were formed late in the Devonian period. It was, of course, useless to talk about the association of petroleum and coal when dealing with Ordovician and Cambrian oil, and its origin from terrestrial vegetation was open to question. His own view was that that oil was formed from whatever organic matter was available at those periods, and in the places where it was formed. The burden of proof that early Palæozoic oil was formed from terrestrial vegetation rested with the author. He (the speaker) did not envy him his task of supplying proof without evidence. With regard to the origin of oil in general, his study of the association of oil with lignites, salt, gypsum, sulphur, and also fossil remains, had led him to believe that there were two types of oilfields, the first being the lignitic type, in which there was an evident relationship with lignite, coal,

and plant remains, as exemplified by the oilfields of Assam, Arakan, Borneo, the Mid-Continent fields, and even Burma to some extent; and the second the salt-gypsum type, in which beds and masses of rock salt and gypsum were associated with the oil measures, as exemplified by the oilfields of the Punjab, Persia, Egypt, California, Texas, Louisiana, etc., etc. That classification was not of fundamental importance. It merely indicated that oil measures of the lignitic type were deposited in areas where there was a moist climate, and that oil-measures of the salt-gypsum type were deposited in areas where the climate was dry. With regard to the conditions under which oil-measures were deposited, in Burma they were obviously laid down in a gulf or a funnel sea. Furthermore, in the central part of Burma the Upper Pegu rocks contained gypsum, and gave out efflorescent salts. Those were evidences of dessication, and indicated that the sea became partly cut off from the open ocean, and thus allowed of concentration of the waters of the gulf. It was equally certain that the oil-measures of Assam were deposited in a gulf. The position of the Shillong plateau suggested that the upper portion of the gulf might have been partly or even wholly cut off from the open sea while the oil measures were being deposited. The oil measures of the Punjab were obviously laid down in a gulf. Mr. Pinfold had explained that the sea was cut off from the open ocean, and that the oil was formed under inland sea conditions. In the case of Persia, the evidence showed that there was a barrier in the neighbourhood of Mahommerah in Tertiary times. The sea in which the oil measures were deposited was either cut off entirely from the open ocean or was connected with it by only a narrow channel. During the deposition of the Tertiaries of South-Eastern Europe there were evidently transgressions and regressions of the sea, and during periods of regression or uplift portions of the sea became isolated from the main ocean. In the Coalinga field there were several unconformabilities within the oil measures, which showed that transgressions and regressions of the sea occurred, and as the oil measures were loaded with gypsum the sea-water evidently became concentrated under inland sea conditions. The history of the deposition of sediment in the Appalachian trough also suggested that those seas might at various times have been partially or wholly cut off from the main ocean. From the above-mentioned and other examples which indicated the conditions under which oil measures were deposited, he thought that they were in a position to postulate that oil in large quantities was formed from organic matter which had been deposited in bodies of salt water of limited size, and which were cut off from oceanic circulation. During the voyage of the Challenger, blue muds were found everywhere on the approach to land. The proximity of land could be predicted anywhere by the presence of those blue muds. The blue colour of

the muds was due to organic matter. Incidentally, it might be mentioned that mud of an intensely blue colour was found in the bailings in oilfields. Now, as that blue mud occurred everywhere as a marginal deposit around land masses, it was suggested that in sheltered lagoons, bays, gulfs, and funnel seas, the muds probably contained very considerable quantities of organic matter. In those sheltered and comparatively stagnant sea areas, not only might large quantities of organic matter become trapped in limited areas, but another important change occurred. The isolation from ocean currents and all oceanic circulation had important consequences. Not only did it provide excellent limited receptacles for the accumulation of organic matter, but owing to the lack of ocean currents, the bottom living organisms soon consumed all the available oxygen. Walther said that as long as a part of the sea was in open circulation with the ocean, and its waters were constantly interchanged and the normal salinity maintained, there would live and be continued a normal marine fauna. As soon, however, as the free circulation of the water ceased, all normal conditions were altered. Such stagnant places were characterised by accumulations of organic matter, by the development of poisonous sulphuretted hydrogen in the water, and by the vanishing of bottom living organisms. The author's principal objection to the view that oil had been formed from animal remains was that the soft parts were eaten by predatory gastropods and by crustaceans. He hoped that the author would appreciate that under the conditions outlined above the predatory forms were killed off at an early stage. With the disappearance of the author's main objection, he (the speaker) took it that he would logically admit that there was no valid reason why animal remains should not have contributed largely to the formation of petroleum. Pirsson and Schuchert stated that "such bottom waters are said to be stale, and that they are taken possession of by sulphur-making bacteria which feed upon the micro-organisms and other life that falls from the sunlit, oxygen absorbing surface zone. As a result of the bacterial life processes, the bottom waters become more and more foul through the liberation of sulphuretted hydrogen gas." Emmons referred to a sulphur bacillus, and even to a petroleum bacillus. Spielmann had quite recently summed up the matter as follows: "The remains of animal and vegetable matter, accumulating rapidly at the bottom of saline or brackish seas or lagoons, became attacked by aerobic bacteria, which caused the decomposition of protein matter mainly to soluble substances and gas. The fats became split by bacterial action or by hydrolysis, to form soluble glycerine and fatty acids. The presence of saline substances in the water caused an increased accumulation of fatty acids, and, modifying the ordinary course of decay, caused the decomposition

to proceed in the direction of petroleum." When that stage in the formation of petroleum had been reached he thought it was the duty of a Geologist to hand over the subject to the Petroleum Chemists who were present at the meeting.

Dr. Dunstan said he had attended the meeting for the purpose of learning something definite about the origin of petroleum and the theories that were put forward in connection with it, because of all branches of scientific enquiry, that of the origin of petroleum was one of the most backward. It was a well-known postulate that organic matter had been resolved into glycerol and fatty acids, and he desired to ask the author how fatty acids would produce petroleum. So far as he understood the paper, the author had brought forward an entirely new theory of the origin of petroleum, namely, a Berginisation of organic matter. That presupposed the existence of a tremendous quantity of hydrogen.

Mr. Cunningham Craig, interposing, said that that was not so, according to his theory.

Dr. Dunstan, continuing, said that during the last year or so he had carried out quite a number of Berginisations of coal and oil ; he had had the opportunity of seeing Bergius's own work, and one of the fundamental points that Bergius claimed was hydrogenation of organic matter, using hydrogen at extremely high pressures and at relatively high temperatures (circa 400° C.). But that did not produce petroleum, in fact the substance he made was not at all like petroleum.

Mr. Cunningham Craig asked what it was like.

Dr. Dunstan said it was a fluid which contained hydrocarbons and nitrogenous substances, phenolic bodies and reduced phenols. It was highly unsaturated ; in fact it would be necessary to go a long way to find a material more unlike ordinary mineral oil. The next question he wished to ask was : What was petroleum ? There was an old tag : *tot homines quot sententiæ*. That tag might be varied in the following way : *tot olea quot origines*. Was it necessary to postulate one kind of origin for the innumerable varieties of petroleum known to exist at the present time ? Some contained oxygen in quantities ; others contained sulphur ; some contained nitrogen ; some contained benzole, naphthalene and other aromatic hydrocarbons, and others did not. Some contained considerable amounts of unsaturated hydrocarbon ; others did not. Some contained paraffin hydrocarbons in the main, some contained chiefly naphthenes. It was impossible to imagine a more diverse natural material, and yet the author sought to postulate one common origin for all the varieties. The first information he

therefore desired from the author was a definition of petroleum. Dealing with one or two points more in detail, he would like to know if any investigator, geological or chemical, had tried to give an explanation of the occurrence of benzole, toluol and xylol in quite a number of petroleums. Generally speaking, those who had worked on the cracking of oil knew that to produce this type of hydrocarbon, high temperature was required; a temperature over red heat. But aromatic bodies might be obtained by synthetic means, by the intervention of catalysts; it was, however, difficult, contemplating the occurrence of ordinary petroleum to visualise such a process. He hoped the author would deal with that point in his reply. Dealing next with the remarkable transition between, say, stearic acid and palmitic acids and the range of hydrocarbons in petroleum it was a curious fact that natural fatty acids usually contained an even number of carbon atoms, generally 16 or 18. The carbon dioxide having been eliminated from the fatty acid, how was the whole range of hydrocarbons from C_1 up to C_{40} or C_{50}. obtained? What was the *modus operandi* of that extraordinary change? Another question he wished to ask was, where the vast amount of methane associated with petroleum came from. He had seen statistics giving the relation of the quantity of natural gas to liquid petroleum, and it was certainly not an insignificant ratio. What was the origin of the methane? Was it possible that methane and the oil were connected in some reversible way? He raised that question because an investigator named Tausz had isolated, some two or three years ago, a specific bacterium which had the remarkable power of assimilating heptane and not cycloparaffins. Bacteria, he presumed, operated in view of the enzymes contained in them. Enzymes were catalysts, and catalysts did not alter the equilibrium of re-action; so that if there was equilibrium between methane and heptane why should not it be assumed that petroleum was an equilibrium product of methane brought about by bacterial change?

Mr. Nash had anticipated him by asking the question as to what happened to the phosphorus and the nitrogen content of animal matter.

What happened to the iodine content if vegetation was largely responsible? Was there any valid reason why more iodine should not be found in petroleum than was the case? The final point he wished to mention was that he was informed by Dr. Dvorkovitz that in the University of Moscow there was a meteorite which contained petroleum.

Dr. P. E. Spielmann thought the paper was of particular value because it emphasised the vegetable origin of petroleum which had not received the emphasis that the animal origin had, and in par-

ticular the introduction of the torbanites and lignites had given a very valuable link in the chain. He suggested, therefore, that the title of the paper should have been "Recent Researches bearing upon *an* origin of Petroleum," rather than "*the* origin of Petroleum." In taking a survey of the whole question it was interesting to find that the many researches which had been made did not tend to culminate towards one final point, but seemed to spread out. The tendency of modern investigators appeared to be to take each petroleum as a separate problem and to attempt to elucidate it on its own merits rather than to try to fit it into any particular theory. There had been a great breaking down of the water-tight compartments which had been preserved up till more recent years concerning animal or vegetable remains, including seaweed, *algæ*, and so on; and even at the present time, as in connection with the hydrogenation idea, theories had been borrowed from the pure inorganic chemist to help the organic chemist over his troubles at certain stages. Even the inorganic theories were dying very hard. There were not very many of them left, but their supporters were putting up a very vigorous, if losing, fight. Coste's discussions with Höffer were very interesting reading, and even the rampageous contempt of the Frenchman, Rigaud, for his opponents made exhilarating, if amusing, reading. The whole object of experimenters was to determine the origin of petroleum, and he wished to say with the greatest possible respect that he did not think the very best had been made of the attempts to solve the problem. As a general rule it was found that investigators did very remarkable work, but in his opinion a satisfactory solution would ultimately be found not in individual, but in team work. An inkling of that was given in the very brilliant results obtained from the association of Engler with Höfer, and if only the chemists, the geologists, the physicists, the microscopists, and the bacteriologists could be induced to act in association, and investigate each type of oil specifically, making, if necessary, a very large number of researches, he thought the problem would be solved all the faster. He would suggest that one addendum should be made to the paper, namely, that the author should give some indication of his ideas as to where the very large amount of elemental hydrogen came from to effect the hydrogenation of the vegetable matter when in the earth.

The President announced that Prof. Zelinsky, a most eminent chemist, was present at the meeting, and that he believed Dr. Dvorkovitz would be prepared to interpret any remarks that Prof. Zelinsky would like to make.

Dr. Dvorkovitz said that **Prof. Zelinsky**, of the University of Moscow, had been working a great deal for the last three or four years on the subject dealt with in the paper. There were huge

deposits of sapropel in Russia, and a special Committee had been formed in Moscow for the purpose of investigating its chemical and geological nature. Prof. Zelinsky had carried out many experiments on quite a large scale in the distillation of sapropel, and had obtained petroleum products absolutely of the same nature as were found in ordinary petroleum. Prof. Zelinsky shared the opinion which had been expressed by Potonie in regard to the origin of petroleum from sapropelite.

Dr. W. R. Ormandy thought the outstanding fact in the discussion that had taken place on the formation of petroleum seemed to be the difficulty which its most learned exponents possessed in putting forward a case in such simple language that the ordinary layman could understand it. They went a certain distance with the greatest clarity, and then their remarks reminded one of systems of philosophy, namely, that as long as the first chapter was accepted all the rest followed. The author stated, regarding the volcanic hypothesis, that the geological evidence in reference to this origin of petroleum was open to at least two entirely contradictory interpretations. That seemed to be characteristic of most geological theories. He further stated that while the vegetable origin theory was chiefly held by geologists, the other was merely a chemical theory. The author did not say it in those words, but it was implied. Some very pertinent points had been raised in the questions put forward by Dr. Dunstan. It seemed to be impossible to imagine that all the varieties of petroleum should have been produced by one series of conditions; it was necessary to look for a lot of conditions to account for the formation of such varied products. It had been stated by one of the speakers that in one case a layer of lignite was found, and immediately above, and in contact with it, an asphaltic sandstone, or shale. Modern work on bacteriology had shown that when large masses of organic matter were allowed to ferment, *i.e.*, either in the presence or absence of oxygen, methane might be produced and it was possible to conceive that the particular ingredient of what was the raw material of the lignite, which it was known did ferment under such conditions—*i.e.*, cellulose, had resulted, in the case quoted in the formation of methane. Was it utterly impossible, therefore, that some of the reactions which it was known methane could undergo should have taken place in the presence of some catalysing material, particularly having in view that some of the most active catalysts known, namely, vanadium and nickel, were so frequently found as a residue of certain types of petroleum. It was hard to believe that any one theory would answer all the cases. Dr. Dunstan had asked how it was possible to convert the fatty acids into paraffins. He believed Maille had shown that all the organic animal and vegetable oils

could be converted into paraffin like bodies by simply heating them at not very high pressure in the presence of those chlorides which took up water, such as zinc and aluminium chloride. In the theory that the organic matters from which petroleum had been formed had been deposited in great sea-beds the presence of magnesium chloride would be postulated, and magnesium chloride was exactly the type of chloride which might bring about that sort of reaction. That point went to show that the problem was vastly more complicated than at first sight it appeared to be. He thought a great deal of investigation required to be done in regard to the relative chemical constitution, the amount of aromatics, the amount of naphthenic products, in the various types of oils, and that regard should be had to each of them in the light of the geological conditions obtaining in that particular field where the oil was found. He thought one of the most valuable papers from that point of view would prove to be that read by Mr. Kewley* showing the relationship of the peculiar oils that were found in the particular district dealt with to the geological formation surrounding it.

Mr. Madgwick thought that the remarks of Dr. Dunstan and Dr. Spielmann had shown the wide range of ideas which required to be dealt with in this subject, as well as the difficulties in correlating the chemical and the geological points of view. However, whether there was ever to be any definite decision on the matter or not, he thought it possible to approximate their ideas as to how oil might be formed with the data derived from the actual study of the rocks associated with oil formations, such as coals, cannels, torbanite, and shales, a research in which, as the author rightly pointed out, very real progress was being made.

Speaking as a geologist the grounds for believing that vegetable matter had contributed to, if not forming the bulk of the oil, were becoming strengthened. It would be wise, however, to avoid generalisations and the door ought to be left open, for both the inorganic and the animal hypotheses. Personally he had always had a kindly feeling towards the vegetable hypothesis, as to which Dr. Dvorkovitz, in a very early number of the *Petroleum Review*, had given Radziszewski's views, which, in spite of their obvious defects, had then appealed to him. Now, modern ideas as to colloids had come to help us out, and he thought that, given the possibility of the precipitation of organic matter in the deltas or estuaries of big tropical rivers when the highly-charged waters meet the electrolytes of the sea water, it was only necessary to bear in mind that this organic material might be of animal origin, as well as the degredation products of cellulose. The resulting muds could certainly then furnish the raw material for petroleum.

* "The Crude Oils of Borneo." *Journ. Inst. Petr. Techn.*, vii., pp. 209-233. 1921.

The author had called attention to the fact that the "gels" could not have been deposited as solid bodies because they had sometimes developed across the lamination. The very interesting slides shown did not appear to illustrate this, and there was much more of a flattening, of which the slides of the Staffordshire and South African Torbanites had been good examples. Supposing the idea were adopted that the organic matter had been precipitated together with silica, the resulting "gels" could have been plastic and it would be mere conjecture how long they remained in that state. It was conceivable that they might have shrunk simultaneously with the mud and thus we might be able to account for the lack of fracture of lamination, but on the other hand, there might have been a process of growth, similar to that of flints, and the small dimensions of these particular segregations be due to the relative insolubility of shale as compared with a limestone. The author appeared to favour a growth.

In a paper read by Mr. Conacher, before the Geological Society of Glasgow, some excellent slides of torbanite, in which there was a kind of skeleton structure in the "gels," were shown. Such a structure if it were due to shrinkage, might easily afford room for the infiltration of silica up to the 20 per cent. quoted by the author from Prof. Flynn's work.

He was not quite sure what the author wished the members to understand from the succession shown in Fig. 1. The difference of zones might be explainable by difference of conditions of deposition, such as due to advance of the deltaic conditions over a wider area seawards; did the author mean that it was solely one of extra loading and temperature which determined the change from oil to coal? This association of coals with oil was much more general than was usually supposed, for he took it that a workable seam of coal or lignite was not a necessity. In many cases where such did not exist there were beds with much lignitic material.

In his opinion there was only one way of tackling the subject satisfactorily, and that was in co-operation with all other Societies and Institutions interested in this class of research. Thus the great amount of work now being done on the nature and origin of coal might have no immediate bearing on oil, yet a careful comparative study be of great mutual benefit.

Mr. A. Struben said he desired to add to the discussion a little evidence from the field which might be of use in starting a line of thought that would be of benefit in settling the conflict of opinion that existed between the geologist and the chemist. He knew the very extensive torbanite deposit of the Transvaal referred to by the author. It was very well developed, and occurred in a composite seam of coal and torbanite. In this seam there is a band of

bright coal, 2 to 4 inches thick, beneath the torbanite, which is approximately from 10 to 18 inches thick, and covered by from 18 inches to 2 feet of good coal. There is nothing parting the torbanite and the coal, which are superimposed on each other in distinct, definite bands. That was a piece of information from the field which might be of value to those interested in the subject.

He desired also to say a few words, which perhaps might not be strictly technical, namely, that torbanite appeared to him, from the author's very able description, to be a material that would become of Empire significance. If it contained, as the author stated, " stillborn " petroleum, which could be retorted, as evidenced by the samples of refined oils exhibited, and it showed that it would be of vital importance to those portions of the Empire in which free oil did not exist. In a country like South Africa the evidences of free oil were very poor, and it might be assumed that no free oil would be found within the Union, whereas torbanite gave possibilities of producing high quality petroleum, which was a key article in any country.

The matter was of such importance to portions of the Empire like Australia, Nova Scotia, and South Africa, that he was sure the subject would receive the greatest consideration from the Institution, because anything that would enable a substance capable of yielding petroleum to be used would be of benefit to the Empire as a whole.

He further thought the Governments of the countries concerned might be invited to support an industry for extracting oil from torbanite, and he appealed to all those present who were endeavouring to solve the problem of the origin of petroleum, to endeavour at the same time to develop practical methods for the best treatment of such minerals as torbanite.

Mr. E. R. Redgrove said he was afraid he was one of those who, in spite of the author's excellent paper, was not quite convinced that the case for the vegetable origin of oil was as clear as could be desired. In view of the excellent slides which had been shown some of the members might be inclined to wave a flag and say the battle was over. It must be borne in mind, however, that the oil which was distilled from torbanites was very different, except in the lighter fractions and the wax, from the oil which was obtained from most wells. He also desired to point out that the nearest approach to crude petroleum had been obtained by purely synthetic methods ; *i.e.*, carbon monoxide, hydrogen, etc., with such catalysts as vanadium and nickel. Personally, he did not think the case was at all clear. The vegetable theory was, he thought, true in many cases with regard to torbanites and shales ; but the animal theory also, apparently, held good in some cases, and he did not think the case for the inorganic origin of petroleum had been at all disposed of.

Mr. Cunningham Craig, in reply, said that he entirely agreed with much of what Mr. Dewhurst had said, but he had, apparently, missed the point in speaking about the association of coals and lignites with oil. The writer had dealt with the *relations* of coal to oil, not the *association*, which is an entirely different matter, and which is no very strong argument for the vegetable theory. All through Mr. Dewhurst's remarks he refers to the association rather than the relations. The diagram shown makes it quite clear that coal, or lignite, and oil overlap; this the writer had seen in many parts of the world, but in a thick series the coal is always more characteristic of the upper part, and the oil of the lower. The evidence given by Mr. Dewhurst is quite in accordance with the diagram. He would like to know if Mr. Dewhurst really suggests that terrestrial vegetation did not make its appearance till Silurian times? That is a proposition with which he thought no geologist would be likely to agree, though, admittedly, the traces of vegetation in the older strata may be very badly preserved, if they have not disappeared altogether.

With regard to the two types of measures, mentioned by Mr. Dewhurst, in which oil occurs, the writer did not see the possibility of making such a distinction: petroleum occurs under all sorts of conditions and in all types of strata, and Mr. Dewhurst must remember that the strata formed in basins of dessication in Persia, Egypt, and even Texas, are of much later date than the petroleum.

With regard to the blue muds, to which reference has been made, if Mr. Dewhurst had had to study such blue muds on coast-lines as the writer had done, and had had them sampled from different depths and analysed, he would have found that the organic matter in them disappeared almost entirely at a depth of about two feet; the very colour of the blue mud was caused by the decomposition of the organic matter reducing the iron salts. He was afraid that Mr. Dewhurst had rather misrepresented the writer's views when he suggested that the principal objection to the animal theory was that the debris of animal matter is eaten by marine scavengers. One of the objections to the animal theory is certainly the difficulty, or one may even say the impossibility, of accumulating animal matter in large quantities and entombing it in sedimentary strata. This is a matter of fact and of observation, but it is only one of the very many objections to the animal origin theory.

In reply to Dr. Dunstan, Dr. Ormandy and others, Mr. Cunningham Craig had no wish to saddle the chemists with the responsibility for starting the animal origin theory, though it was certainly true that that theory is more held by chemists than by geologists. It is very difficult for chemists and geologists to meet on even terms to discuss such a question, as each speaks his own

jargon and produces his own evidence. The writer, however, agrees with Dr. Spielmann that by team work between geologists and chemists the question can certainly be threshed out and settled. With regard to the hydrogenation of coals he thought he had made it quite clear that before the coal stage had been reached the vegetable deposits contained a sufficient percentage of hydrogen to enable petroleum to be formed; of course, after the coal stage had been reached the addition of hydrogen became necessary. Naturally the oils made by the Bergius Process differed from crude petroleum; they are formed at much higher temperatures, and so contained carbon-ring compounds in greater quantity, as well as other compounds characteristic of oils formed by distillation of coals.

As to the definition of petroleum, the writer left it to chemists like Dr. Dunstan; he, himself, was content in knowing petroleum when he found it.

In further reply to Dr. Dunstan, it was not for the geologist to state the various chemical reactions involved in the formation of petroleum, but merely to determine the physical conditions under which it had been formed. Variations, within certain limits in temperature and pressure, were sufficient to account for the formation of very many different fractions. The association of methane with petroleum, or for that matter, with coal, was well-known for many years, and the disengagement of that gas from oil when the fluid is struck in a well and pressure naturally suddenly reduced is a point that has not perhaps received sufficient attention.

Iodine has been recorded from the water of many mud-volcanoes marking petroleum fields, and even phosphorus has been detected in minute traces in petroleum.

That a meteorite has been proved to contain traces of petroleum is not very strange; the same can be said of many intrusive igneous rocks, but the petroleum is "cracked."

In answer to Mr. Madgwick, the author regretted that the light was not strong enough to show up all details of the microscope slides upon the screen. Had it been brighter, Mr. Madgwick would have seen that the gels, though orientated along lines of lamination, do cross those lines and do not disturb them. These gels are slightly flattened in many cases, but not very greatly, as gels show enormous resistance to deformation.

Dealing with the discussion generally, the author would like to point out that many of those speaking seemed to treat the subject as if it were a new one that had not been gone into very thoroughly. Chemists were apt to write of how petroleum *might* be formed, or *can* be formed, under certain conditions and from certain materials, but they seem to avoid the main question of how petroleum *has*

been formed. The conditions under which it has been formed can be defined with very fair accuracy, *viz.*, a natural autoclave, comparatively low temperature, high pressure, and probably the presence of water, not in excess. As regards the materials from which it can be formed, we know of vast accumulations of vegetable matter of all kinds, but we do not know of similar accumulations of animal matter, nor has anyone ever been able to prove that such accumulations do exist, or can ever have existed. The torbanites show quite distinctly the formation of petroleum from vegetable matter under adverse conditions. No such evidence has been forthcoming in the case of animal matter, and the writer would be very glad to hear of any such unequivocal evidence that can be produced.

The President said he was sure all the members had very much enjoyed the author's excellent paper. Although it could not be stated that the discussion had decided the question of the origin of petroleum, there was every reason to hope that they had moved a step in that direction. It afforded him much pleasure to move that a hearty vote of thanks be accorded to the author for his excellent paper.

The resolution of thanks was carried by acclamation, and the meeting terminated.

Equilibrium Boiling-point and Latent Heat of Vaporisation of Motor Fuels.*

By W. R. ORMANDY and E. C. CRAVEN.

THE latent heat of vaporisation is one of the factors which influences the value of a motor fuel. There is no doubt that most fuels enter the cylinder in the liquid state, and that considerable cooling of the engine cylinder occurs from the heat required to vaporise this liquid fuel. Also the vaporisation which does occur to some extent in the carburetter results in a considerable drop in temperature of the vapour in the induction pipe. Mr. Tizard† calculates that, if all the fuel evaporated before reaching the cylinder, the drop in temperature would be 25° C. for petrol and 33° C. for benzol. These two factors, the cooling of the cylinder and the drop in temperature of the induction pipe, are dependent on the magnitude of the latent heat of evaporation of the fuel, and on these two factors the volumetric efficiency of the engine to a large extent depends.

The latent heat value usually considered is that at round about room temperature, presumably on the basis that the evaporation in the carburetter occurs at ordinary temperatures. While this is true so far as it goes, it is much more likely that the bulk of the evaporation occurs at the boiling-point of the fuel, or perhaps somewhat above if evaporation continues on the compression stroke.

One of the main difficulties in endeavouring to determine experimentally the latent heat of a mixture such as petrol is that of bringing about the complete vaporisation of the mixture under isothermal conditions. Some work by G. Keith and W. A. Whatmough.‡ suggested to us how this difficulty might be overcome. These authors distilled petrol and other fuel from a lagged still provided with a constant level arrangement, so that the petrol flowed into the still at exactly the same rate as it distilled. They found that ultimately a steady state was reached, the vapours coming over at a constant temperature and having the same composition as the fuel feed. This temperature they refer to as the equilibrium boiling-point.

There is some doubt as to the true existence of a definite equilibrium boiling-point in the case of such a complex mixture as petrol, but in practice it is observed that, with a boiler of about 40 c.c.

* Published by permission of the Department of Scientific and Industrial Research.

† Private communication.

‡ *J. Inst. Automobile Eng.*

capacity, several litres of petrol can be distilled through without the temperature varying more than 1° C.

In the case of a binary mixture it is obvious that a true equilibrium boiling-point is theoretically possible. When the steady state of distillation is reached

Let $m_l = m_v$ = weight per cent. of component A in feed and vapour,
and m_s = " " " " in still liquid,

We have by Brown's formula (2)*

Where C_0 is a constant; a is a correction of factor; M_A is the molecular percentage of A in the still mixture.

$$\frac{m_l}{100-m_l} = \frac{m_v}{100-m_v} = \frac{m_s}{100-m_s}(C_0 + a\,M_A).$$

For the case of liquids miscible in all proportions and feebly associated, for which Speyer's law

$$P = \frac{M_A P_A + (100 - M_B) P_B}{100}$$

holds good, a simpler form of Brown's law appears to hold :—

If P_A as above = vapour pressure of A at the equilibrium b.p.
P_B " = " " B " "

$$\text{Then } \frac{m_l}{100-m_l} = \frac{m_v}{100-m_v} = \frac{m_s}{100-m_s} \cdot \frac{P_A}{P_B}$$

This expression gives the composition of the liquid in the still for any given composition of the vapour, and hence again from Speyer's law the boiling-point of the liquid in the still can be calculated, provided the vapour tension curves of the liquids A and B are available.

For a mixture of n liquids the sum of all the partial pressures of the components in the vapour will be equal to the superincumbent pressure. Thus under atmospheric conditions

$$76 = p_1 + p_2 + p_3 \ldots p_n.$$

The partial volumes of the vapour of each will be proportional to these partial pressures, and the composition can be found if the molecular weight of each constituent be known, and no association occurs in the vapour state. There is no formula for calculating the composition of the liquid mixture which evolves a vapour having the composition calculated as already described, nor indeed is there any theoretical reason for supposing that any such liquid mixture can, in general, be found. It may happen, of course, that a straight distilled mixture of presumably non-associated hydrocarbons, such as a commercial petrol, is somehow by reason of the straight distillation of such a composition, that in the vapour state it can be in equilibrium with the heated residue obtained by distilling off part of the liquid itself.

* S. Young, "Distillation Principles and Processes," 1922, p. 84.

In actual experiments with the Whatmough apparatus it was found that the distillate had never quite the same Engler distillation curve as the original petrol. In particular, the "dry point" of the distillate was low.

The apparatus used for the equilibrium boiling-point and latent heat determination is shown diagrammatically in Fig. 1.

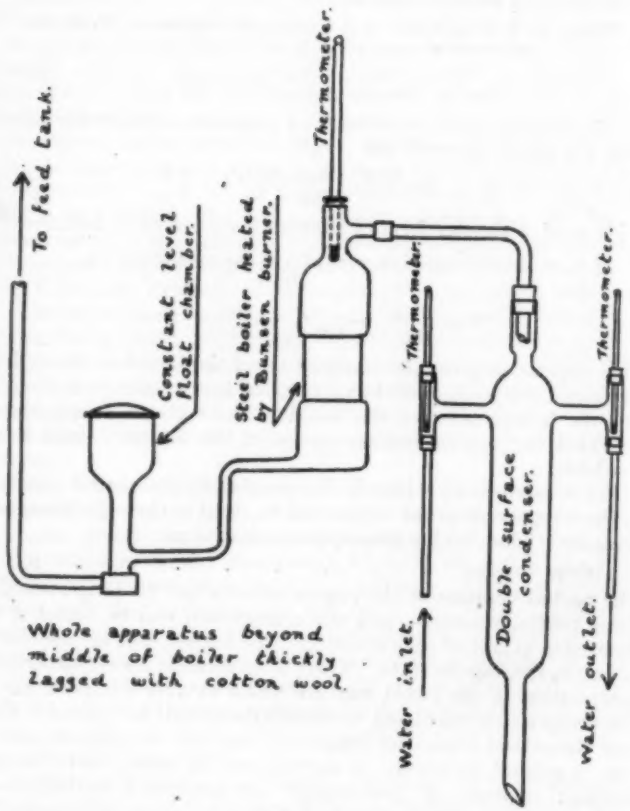


FIG. 1.

A few equilibrium boiling-point determinations were made at the beginning with the thermometer bulb in the hot liquid. The

results are perhaps not worth much, except to enable us to compare the composition of the distillate with the feed. The figures obtained, briefly abstracted, were as follows :—

PETROL—RICARDO B.

Equilibrium b.-p. = 90·5° C. Steady after 100 c.c. over Engler distillation.

	Original. °C.	Distillate (89½–91½° C.) °C.
Drop	42 ..	43
50%	85·5 ..	86
Dry	127·5 ..	125

PETROL—PRATT'S No. 1.

Equilibrium b.-p. = 127° C. Steady after 400 c.c. over Engler distillation.

	Original. °C.	Distillate (126–128° C.) °C.
Drop	44 ..	44
50%	105 ..	106
Dry	183 ..	176

Same petrol repeated, starting with kerosene in boiler.

Equilibrium b.-p. = 128·5. Steady after 150 c.c. over Engler distillation.

	Original. °C.	Distillate (128–129° C.). °C.
Drop	44 ..	46
50%	105 ..	105·5
Dry	183 ..	178

Several litres of this fuel were distilled, and the extreme variation of temperature in the boiler was between 126° C. and 130° C. In general it was found that varying the speed of distillation from about 8 to 32 c.c. per minute made no difference to the temperature shown.

An experiment was also made to determine if the equilibrium boiling-point of a petrol was affected more by the addition of alcohol or of benzene. The results were as follows :—

	Equilibrium b.-p. °C.
Petrol	128
Petrol+25% vol. alcohol*	115
Petrol+25% vol. benzene	117

The equilibrium boiling-point found in each case is somewhat lower than that calculated from the volume and the equilibrium boiling-points of the constituents.

* "Power Methylated Spirit" made from 99·6% vol. alcohol.

In the further experiments in which latent heats were determined as well as the equilibrium boiling-points, the thermometer was placed in the usual manner with the bulb in the vapour as indicated in sketch.

The total heat given up by the vapour in condensing to liquid at room temperatures was measured by a flow calorimeter arrangement as indicated in the figure. The neck of the still, the condenser, and all the water leads were thickly lagged with cotton wool. Experiments were first made with pure liquids. The figures relating to one experiment are given to show what readings were taken, and the manner of calculation of the result. It should be mentioned that in all the following work about 2 litres of the liquid to be tested was put in the feed tank, and the distillate returned at frequent intervals until equilibrium was established. The mixed material in the tank was found to differ but little from the original. This method enabled us to work with smaller samples than would otherwise have been the case.

Benzene.

(Engler distillations are given at end of paper.)

Equilibrium b.-p. = 80° C.

Time.	Outlet water. ° C.	Inlet water. ° C.	Equilibrium b.-p. ° C.
12.12	31·6	17·8	80
13	32·5	17·8	80
14	32·2	17·8	80
15	31·9	17·8	80
16	31·8	17·8	80
17	31·8	17·8	80
18	32·2	17·8	80
19	32·7	17·8	80
20	31·9	17·8	80
21	32·6	17·8	80
Mean	32·12	17·8	80

Weight benzene collected, 58·5 g.

Water collected, 485 c.c.

Heat given up per g. of benzene in cooling from 80° C. to 20° C.*

$$= \frac{14{\cdot}32 \times 485}{58{\cdot}5} = 118{\cdot}7 \text{ cals.}$$

A second determination gave 120·7 cals.

$$\text{mean} = 120 \text{ cals.}$$

The heat given up per g. of liquid benzene in cooling from 80° to 20° = 60 × 0·45 = 27 cals.

* The condensed liquid appeared to be in all cases some 2° higher in temperature than the cooling water.

∴ Latent heat of evaporation of benzene at 80° C. = 93 cals/gm.

The figure given by Young* is 95·5 gm. Hence the error of the determination = —3 per cent.

This, no doubt, represents heat lost at the neck of the still, where it was not possible to lag very far with cotton wool.

Heptane.

Equilibrium b.-p. = 98·5° C.

Total heat 98·5° C. to 20° C. = (1) 113·2; (2) 114·0; (3) 112·9. Mean = 113 cals/gm.

Correction for liquid cooling = 78 × 0·5 = 39 cals/gm.

Latent heat at 98·5° C. = 74 cals/gm.

Young gives 76 cals/gm.

Error = —3 per cent.

Methyl Alcohol.

Equilibrium b.-p. = 66° C.

Total heat from 66° C. to 20° C. = (1) 289·8; (2) 228·8; (3) 283·7. Mean = 287 cals/gm.

Correction for liquid cooling = 46 × 0·66 = 30 cals/gm.

Latent heat at 66° C. = 257 cals/gm.

Error = —4 per cent.

Ethyl Alcohol.

Equilibrium b.-p. = 77·5° C.

Total heat from 77·5° to 20° C. = (1) 234·4; (2) 236·7; (3) 230·3; (4) 235·9; (5) 241·4. Mean = 236 cals/gm.

Correction for liquid cooling = 57·5 × 0·6 = 35 cals/gm.

Latent heat at 77·5° C. = 201 cals/gm.

Young gives 207 cals/gm.

Error = —3 per cent.

There thus appears to be a steady error in the determinations of —3 per cent.

On "mixed" liquids the following results were obtained:—

Alcohol-Benzene Mixture.

This was mixed so as to correspond with the minimum boiling-point mixture of the two components. Hence, on Engler distillation the mixture behaved like a pure liquid.

Equilibrium b.-p. = 67° C.

Total heat of evaporation, 20 to 67° C. = (1) 151·0; (2) 152·3; (3) 151·0. Mean 151·4 cals/gm.

Taking the specific heat of the liquid at 0·5, correction for cooling of liquid = 47 × 0·5 = 23·5 cals/gm.

* S. Young, *Sc. Proc. R. Dub. Soc.* (*N.S.*), 12.

∴ Latent heat of evaporation at 67° C. = 128 cals/gm.

The composition of the mixture being 67·6 per cent. benzenes, and 32·4 per cent. alcohol, by weight, we have, calculating proportionately from the determined total heat figures for alcohol and benzene :—

Calculated total heat of mixture, 20–79°* = 0·324 × 0·236 + 0·676 × 120 = 157 cals/gm.

Correction for heating liquid, 12° C. = 6 cals/gm.

∴ calculated total heat of vaporisation of mixture, 20 to 67° = 151 cals/gm.

The calculated value thus agrees exactly with that observed.

Motor Benzole.

Equilibrium b.-p. = 97° C.

Total heat of evaporation, 20 to 97° C. = (1) 112·8 ; (2) 118·1 ; (3) 117·2 ; (4) 114·6 ; (5) 117·6. Mean 116 cals/gm.

Corrections for liquid cooling = 77 × 0·45 = 34 cals/gm.

∴ Latent heat of evaporation at 97° C. = 82 cals/gm.

Pratt's No. 1 Petrol.

Equilibrium b.-p. = 120·5° C.

Total heat of evaporation, 20 to 120·5° C. = (1) 113·4 ; (2) 119·2 ; (3) 120·2 ; (4) 116·5. Mean 117 cals/gm.

Correction for liquid cooling = 100 × 0·45 = 45 cals/gm.

∴ Latent heat of evaporation at 120·5° C. = 72 cals/gm.

Shell Petrol.

Equilibrium b.-p. = 121° C.

Total heat of evaporation, 20 to 121° C. = (1) 119·2 ; (2) 116·6 ; (3) 115·8. Mean 117 cals/gm.

Correction for liquid cooling = 101 × 0·45 = 45 cals/gm.

∴ Latent heat of evaporation at 121° C. = 72 cals/gm.

Shale Petrol.

Equilibrium b.-p. = 111° C.

Total heat of evaporation, 20 to 111° C. = (1) 114·6 ; (2) 116·1 ; (3) 119·6 ; (4) 116·0. Mean 117 cals/gm.

Correction for liquid cooling = 91 × 0·45 = 41 cals/gm.

∴ Latent heat of evaporation at 110° C. = 76 cals/gm.

* Mean of boiling-point of alcohol and benzenes.

Ordinary "Discol" Fuel.

Equilibrium b.-p. = 100·5° C.

Total heat of evaporation, 20 to 100·5° C. = (1) 188; (2) 188. Mean 188 cals/gm.

Correction for liquid cooling = 80 × 0·5 = 40 cals/gm.

∴ Latent heat of evaporation at 100·5° C. = 148 cals/gm.

"H.L.H. Discol."*

Equilibrium b.-p. = 73° C.

Total heat of evaporation, 20 to 73° C. = (1) 270; (2) 253; (3) 252; (4) 272. Mean 262 cals/gm.

Correction for liquid cooling = 53 × 0·6 = 32 cals/gm.

∴ Latent heat of evaporation at 73° C. = 230 cals/gm.

H.H.V. Discol.†

Equilibrium b.-p. = 71° C.

Total heat of evaporation, 20 to 71° C. = (1) 203; (2) 201. Mean 202 cals/gm.

Correction for liquid cooling = 51 × 0·6 = 31 cals/gm.

∴ Latent heat of evaporation at 71° C. = 171 cals/gm.

Power Methylated Spirit.—II.

Equilibrium b.-p. = 75° C.

Total heat of evaporation, 20 to 75° C. = (1) 216; (2) 218. Mean 217 cals/gm.

Correction for liquid cooling = 55 × 0·57 = 31 cals/gm.

∴ Latent heat at 75° C. = 186 cals/gm.

For the discussion of these results it was desirable to know the mean molecular weights of the fuels employed. Determinations were made by the Victor Meyer method in the usual manner, except that an electric heater was employed instead of a vapour jacket. It was found necessary to employ a temperature exceeding the equilibrium boiling-point of the fuel under test by 100° C. in order to ensure complete vaporisation in 4–5 minutes. The results obtained were :—

	M.
Pratt's No. 1 Petrol	104
Shell Petrol	107
Shale Petrol	101
National Benzole	86
Ordinary Discol	62
H.L.H. Discol	45
H.H.V. Discol	54
P.M.S. II.	52

* H.L.H. = high latent heat. Also known as Ricardo Discol I.

† H.H.V. = high heat value. Also known as Ricardo Discol II.

Each figure being the mean of two or more determinations. Some check measures were also made on pure benzene, and the results appear to be within 3 per cent. of the truth.

Starting from the classical Clausius-Clapeyron equation for the calculation of latent heats :—

$$l = T\frac{dp}{dT}(v - v^1)$$

and introducing the assumption the simple gas laws can be applied and, neglecting V^1, we get the relation :—

$$Ml = \frac{RT^2 d(\log_e P)}{dT}$$

$$\text{or } l = \frac{4{\cdot}571T^2 d(\log_{10} P)}{dTM}$$

Since the value of $\frac{dp}{dT}$ is not in general known for any given fuel, it would be necessary to determine the slope of the vapour tension curve at the particular temperature at which the latent heat was required.

When dealing with hydrocarbons however, the rule of Ramsay and Young will take us rather further, since it follows directly that the value of $\frac{dp}{dT}$ is inversely proportional to T. This is the well-known rule of Crafts for the correction of boiling points for variation in pressure.

$$dt = c(76 - p)T$$

where c is a constant for hydrocarbons and other liquids not highly associated.

Taking the values of $\frac{pd}{dT}$ for all the hydrocarbons given by Young we can construct a table as below :—

Substance.	$\frac{dp}{dT}$	$\frac{d \log_{10} P}{dT}$	$d \log_{10} P \frac{T}{dT}$	T.
Pentane	25·8	0·01474	4·56	309·3
n-Hexane	23·9	0·01366	4·67	342·0
n-Heptane	22·3	0·01275	4·74	371·4
n-Octane	21·1	0·01205	4·81	398·8
Isopentane	26·2	0·01497	4·51	301·0
Methane	68·2	0·0390	4·22	108·3
Benzene	23·45	0·01341	4·73	353·2
Toluene	21·75	0·01242	4·76	383·7
Ethyl Benzene	20·3	0·01159	4·74	409·2
m-Xylene	21·1	0·01205	4·97	412·0
Anthracene	15·0	0·00859	5·28	616·0
Naphthalene	17·1	0·00977	4·80	491·0
Tri-phenyl Methane ..	14·8	0·00846	5·30	626·0
Hexamethylene	22·7	0·01297	4·60	353·9
Di iso Butyl	20·9	0·01194	4·96	382·1

The very fair constancy of the value $d \log_{10} p \frac{T}{dT}$ confirms Crafts' rule. Taking only such bodies amongst those given as are likely to occur in petrol, the values do not vary more than 2–3 per cent. from the mean :—

Benzene	4·73
Toluene	4·76
Hexamethylene	4·60
n-Hexane	4·67
n-Heptane	4·74
n-Octane	4·81
Mean	4·72

Reverting to the derived equation for 1 and substituting the above mean value we have

$$l = \frac{4{\cdot}571\ T \times 4{\cdot}72}{M}$$
$$= 21{\cdot}5 \frac{T}{M}$$

The simple relation thus derived is known as Trouton's rule. It is found experimentally that the constant in the formula is better taken at 20·7* for hydrocarbons. This formula can be applied to all pure hydrocarbons, but in the cases of mixtures some doubt exists as to what temperature we are to consider the boiling-point. Taking the equilibrium boiling-point as the boiling-point and increasing our latent heat measures by the constant error of 3 per cent. the following figures are obtained :—

	Equilibrium b.-p. ° K.	M.	l calculated.	l observed. Cals/gm.
Heptane	371	100	76·9	76
Benzene	353	78	93·6	96
National Benzole	370	86	89	84
Pratt's Petrol	394	104	77	74
Shell „	394	107	75	74
Shale „	384	101	77	78

The calculated value thus appear to agree fairly well with the observed.

It is suggested by Holde† to use as the boiling point the average of the drop, dry point and the intermediate nine 10 per cent. fractions in the Engler distillation of the fuel. On this basis the figures are :—

* See for example *W.C.*, Mc. C. Lewis, "A System of Physical Chemistry, 11, 76.

† Holde-Mueller, "Hydrocarbon Oils and Saponifiable Fats and Waxes," 1922, p. 46.

	Average b.-p. ° K.	1 calculated.	1 observed. Cals/gm.
National Benzole	371	89	84
Pratt's Petrol	381	75	74
Shell „	385	74	74
Shale „	378	76	78

The agreement is perhaps slightly closer than when using the equilibrium boiling-points. It will be noticed that the average boiling-points do not agree with the equilibrium boiling-points, and there does not seem to be any exact co-relation between the latter and the Engler distillation curve.

In the case of mixtures containing alcohol or other liquids not conforming to Trouton's rule the composition of these will usually be known. In such cases it appears to be quite accurate to calculate the latent heat by proportion as in the case of the alcohol-benzene mixture mentioned before.

The various mixed alcohol fuels mentioned in this work are composed of varying proportions of some of the following liquids, ethyl alcohol, wood naphtha, acetone, benzole and kerosene or white spirit. The latent heats calculated for each mixture from its composition agreed with the observed value in each case within about 3 per cent., and this appears to be within the limit of experimental error of the method described in this paper.

It may be concluded therefore that for hydrocarbon fuels the methods described by Holde are adequate for technical purposes. Possibly the Victor Meyer method is to be preferred to that of Raoult, since there is the danger that the fuel may be appreciably associated at the temperature of the latter determination, and but little, if any, associated at its boiling point. For the case of alcohol mixtures and the like, calculation based on the weight composition of the fuel is to be recommended.

The authors are indebted to Messrs. G. Keith and W. A. Whatmough for the loan of the equilibrium boiling-point apparatus used in this work. The authors desire to express their thanks also to Mr. E. E. Connolly and Mr. A. M. Peake for carrying out much of the experimental work of these investigations.

This work may be regarded as a further portion of the extended investigation which is being carried out on the physical properties of pure and mixed fuels at the joint request of the Distillers' Company, Ltd., and the Fuel Research Board of the Department of Scientific and Industrial Research. We wish to take this opportunity of recognising the financial assistance rendered by them towards the expenses of this research.

APPENDIX.

Character of liquids employed in the foregoing work.

	Benzene.	Heptane.	Ethyl Alcohol.	Methyl Alcohol.	Alcohol Benzene (binary mixture).
Sp. gr. 15/15° C.	0·8842	0·6890	0·7960	0·7965	—
Engler Distillation—	° C.	° C.	° C.	° C.	° C.
Drop A. at	76	66	76·5	63	65
„ B „	79	86	77·5	64·5	65·5
5% over „	79	97	—	—	66
10% „ „	—	98	—	—	—
20% „ „	—	—	78	—	—
30% „ „	79·5	—	—	—	—
40% „ „	—	98·5	—	65	—
50% „ „	—	—	—	—	—
60% „ „	—	—	—	—	66·5
70% „ „	—	99	—	65·5	—
80% „ „	—	100	78·5	66	—
90% „ „	—	102	—	67	67
95% „ „	80	107	—	69	—
Dry	81	124	81·5	77·5	69

Hydrocarbon Fuels.

	Pratt's.	Shell.	Shale.	National Benzole.
Engler Distillation—	° C.	° C.	° C.	° C.
Drop A	40	50	47	63
„ B.	50	58	60	77
5% over at	68	76	75	82
10% „ „	74	82	80	82
20% „ „	83	92	86	84
30% „ „	91	98	91	85
40% „ „	98	105	96	87
50% „ „	105	110	102	88
60% „ „	112	117	108	90
70% „ „	119	123	114	93
80% „ „	133	132	123	101
90% „ „	149	146	137	20
95% „ „	164	157	149	42
Dry	178	170	160	69

Alcohol Fuels.

	Discol.	H.L.H. Discol.	H.H.V. Discol.	P.M.S.2.
Engler Distillation—	° C.	° C.	° C.	° C.
Drop A.	68	64	62	67
„ B.	69	67	65	69
5% over at	70	68	66	70
10% „ „	71	69	66	71
20% „ „	72	70	67	71
30% „ „	73	71	68	73
40% „ „	73	72	69	74
50% „ „	74	73	70	76
60% „ „	75	74	72	76
70% „ „	77	75	74	77
80% „ „	146	76	76	77
90% „ „	172	77	77	78
95% „ „	188	78	78	79
Dry	198	—	—	—

Some Physical Properties of Lubricants.*

By ELLIOTT A. EVANS, F.C.S.

THE whole process of lubrication is one which involves the aid of the chemist, the physicist, the engineer, and the mathematician. It would therefore be presumptuous on the part of anyone versed only in one branch of the science to dogmatise upon the subject as a whole. Hence it is to be expected that those who are endeavouring to advance the subject find themselves hampered by a tantalising ignorance of one or other of the essential contributory subjects. Consequently it is expedient upon each one of us to record our observations in the hope that they may be of value to others who are working for the common cause of ideal lubrication, and avoid hasty criticisms which are based upon slender evidence. The evidence which is generally available is such physical data as specific gravity, viscosity, and flash point. Valuable as these determinations are, they are of but limited value unless their true interpretation can be applied.

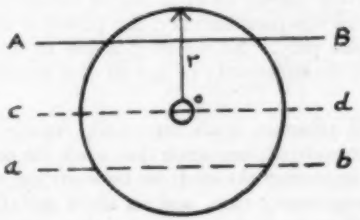
Viscosity plays an important *rôle* in deciding upon an oil to withstand the pressures exerted between moving parts. No laws can be enunciated to define what the viscosity of an oil shall be to maintain two surfaces apart when under pressure, because pressure alone is not the deciding factor. A heavily loaded journal running at a high speed may be lubricated perfectly with a thin oil, whereas one less heavily loaded running at a low speed might require a viscous oil. Compromises have frequently to be made when a journal is working at widely different speeds and under varying loads, and perhaps alternately in opposite directions. It is such conditions as these that render lubrication more of an art than a science, and leave room for imagination and experience to prescribe a lubricant. However helpful scientific investigation may be, and helpful it is, there will always be cases for personal licence in framing the oil specification.

To follow the mechanism of lubrication one must concentrate for a moment upon the oil molecules themselves. These molecules have a certain attractive force which keeps them together in the liquid or solid phase. This attractive force, or intrinsic pressure as it is called, can be measured by determining the latent heat of vaporisation of the substance. To convert 1 gram of water at

* Abstract of paper read before, and published by permission of, the International Air Congress, London, 1923.

100° C. into steam at 100° C., 540 calories must be supplied. These units of heat supplied are really units of energy required to dispel the water molecules from the water phase into the vapour phase. The molecules in the water are exerting a downward pull on the molecules at the surface, consequently, the latent heat is a measure of the downward pull. In addition to the downward pull there is a pressure acting upon the surface, due to the atmosphere, which must be allowed for in determining the intrinsic pressure from the latent heat. The portion of the latent heat used in overcoming the downward pull is called internal latent heat L_i, since it arises from internal cohesive forces, while the portion used to overcome the pressure of the superincumbent atmosphere is called the external latent heat L_e, which depends upon the film of the vapour and the atmospheric pressure to be overcome. If we express the atmospheric pressure in dynes, p, and the film in cubic centimetres of 1 gram of vapour, v, the external latent heat $L_e = p\,r$ ergs, or $p\,v/j$ calories, where j is the mechanical equivalent of heat, 42×10^6. For water at 100° C. L is about 540 calories, L_e about 40, and L_i about 500 calories, or in units of work, $500 \times 42 \times 10^6 = 21 \times 10^9$ ergs.

To connect the internal latent heat with intrinsic pressure we must consider the forces to which a molecule in a liquid is subject. When the molecule is in the interior these forces are equal in all directions, but when the molecule approaches the surface, obviously they are not.



Let O be a molecule in the centre of a sphere equal to the radius of molecular attraction, which is in the neighbourhood of 10^{-7}cms. This radius being r, then only the liquid within that sphere will have any effect on O. In this position the molecule is attracted downwards by the liquid contained in the segment a b, which is equal to A B, as the downward attraction of the portion a b c d is balanced by the upward pull on the upward pull of the portion A B c d. The downward pull increases until the molecule is on the surface, and decreases as O rises farther above the surface, and becomes zero when the distance of O from the surface is equal to r. It follows therefore that half the work of moving the molecule from

the interior of the liquid into the space above is done when the molecule is brought into the surface, and the other half is used in removing the molecule from off the surface. The total work, then, is the internal latent heat L_l, assuming we are dealing with 1 gram of liquid, and the work done in taking this gram off the surface is $\frac{1}{2} L_l$. This work is equal to P ergs, where P is the intrinsic pressure expressed in dynes.

$$\therefore P = 0{\cdot}5 \times 21 \times 10^9 \text{ dynes},$$

but since an atmosphere is approximately 10^6 dynes,

$$P = 0{\cdot}5 \times 21 \times 10^3 = 10{,}500 \text{ atmospheres}.$$

The magnitude of this cohesive force is probably surprising, for a substance like water, whose lubricating power is small as compare with that of the more efficient lubricants such as oils. Unfortunately the intrinsic pressure of oils is extremely difficult to measure.

One gathers from the utterances of Sir J. J. Thompson that the attraction between molecules is of a magnetic character, so therefore the molecules in a lubricant are held together by this magnetic attraction, and when a lubricant is applied to a metallic surface it clings to it by virtue of this attractive force, and its power to withstand pressure exerted by the moving parts of the lubricated surfaces is to be found in its power to adhere to these surfaces ; and since the attractive forces between oils of different character and metals of different composition vary, the power of oils to withstand pressure must also vary. No doubt it is due to this property that we can attribute the superiority of one oil over another oil of similar viscosity.

This power of adhesion is all-important, especially when heavy loads are to be considered, inasmuch that when the oil film is reduced in thickness by squeezing the oil from between the surfaces the film may become dangerously thin, and so allow metallic contact, but if the adhesion be so great, in fact greater than the pressure exerted, the film can be reduced even to molecular dimensions without any fear of metallic contact. Sometimes one hears of a lubricant being described as soft or harsh in its operation. This, doubtless, is due to a cushioning effect in the one case by virtue of its adhesion, and to a temporary breaking of the film in the other, due possibly to impact.

Sommerfeld's work is interesting in that he lays stress upon similar results obtained previously by Thurston, that the coefficient of friction on a bearing is practically independent of the viscosity of the oil used. The outstanding feature of these results is the thickness of the oil film which increases with the viscosity. It

Viscosity of lubricant. C.G.S. units.	Attitude of Bearing.	Eccentricity of Bearing.	Nearest approach. ins.	Coefficient of Friction.
0·223	129°	0·94	6×10^{-5}	0·00094
0·488	135°	0·82	18×10^{-5}	0·00096
0·824	133°	0·65	35×10^{-5}	0·00099

should not be deduced, however, that the viscosity of an oil can be neglected as might be assumed on first sight from these results. Stanton, in his Thomas Hawkesley Lecture, 1922, before the Institution of Mechanical Engineers, describes a method by which the pressure distribution can be measured, also the actual thickness of oil film at the point of highest pressure. His results may be summarised thus :—

	Max. Pressure. (tons/sq. in.)	Coefficient of Friction.	Least distance. (inches).
Sperm	1·44	0·00072	0·000054
Rape	1·38	0·0017	0·000096
Castor	3·5	0·0023	0·000046
FFF (Mineral cylinder oil)	2·8	0·0035	0·000066

Attempts to secure higher pressures with sperm and rape were in vain, due to the risk of seizure. The superiority of castor is clearly manifested, although it has a much lower viscosity than the mineral cylinder oil. The relationship of viscosity to thickness of oil film is in agreement with the results obtained by Sommerfeld.

Attempts to substitute heavy mineral oil for castor oil lubricants in aircraft engines to reap an advantage in initial cost should be pursued with caution, as every nerve of the designer is strained to secure maximum efficiency with maximum safety in flight, and the minimum safety factor with regard to weight of material used in construction. With motor-car engines the use of mineral oil is permissible because the effect of oil failure would only inconvenience, whereas in an aero engine death of the personnel might result.

Since one of the chief problems which faces designers of internal-combustion engines in their endeavour to obtain higher piston speeds is the provision for the pressure on the big-end ; that is to say, the limit of speed is defined by the limiting pressure on the big-end bearing of the connecting rod, it is obviously unsafe to utilise an oil like sperm or rape as the lubricant owing to their risk of seizure. According to Stanton's showing, castor oil is far superior even to a viscous mineral oil. It might be mentioned here that Thurston has shown that sperm oil is only a good lubricant at temperatures below 40° C.

The relative efficiencies of several oils are brought out in rather striking fashion in the Report on Lubricants, issued by the Scientific and Industrial Research Advisory Council in 1920. Hyde, who made the tests, plotted the results which he obtained working with a worm gear to show the variation in efficiency.

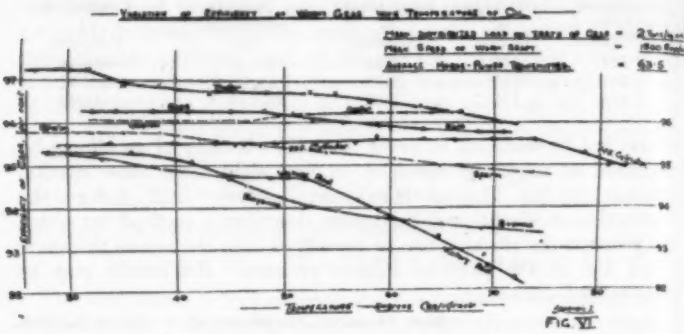


FIG. VI.

In each of these curves it will be noted that as the temperature rises the efficiency diminishes, except in the case of castor oil. Hence it is not merely due to the natural diminution of viscosity. Why it is, still remains to be proved.

Asphalt in Lubricating Oils.

By ELLIOTT A. EVANS, F.C.S.

ARISING out of various opinions expressed by independent workers, as to the asphalt content of the same sample of oil, it became necessary to ascertain the cause of the differences. The results here given, although incomplete, will no doubt be of service in obviating some of the troubles which have been experienced.

The method adopted in the various laboratories was to dilute 5 grams of the oil with 40 vols. petroleum-ether, B.P. 60–80° C., and allow to stand overnight. The precipitate was filtered off, washed, dried, and weighed. The asphalt was weighed on the paper and not dissolved in benzene, as is sometimes done.

Petroleum-ether of this B.P. range was obtained from three distinct sources, and precipitation tests carried out with each; the results being :—

1·59%, 1·67%, and 1·1% respectively.

Each ether was then washed with fuming H_2SO_4 (to free from aromatics) and tests repeated, and consistent results obtained :—

1·64%, 1·63% and 1·7% respectively.

The petroleum-ethers used were then examined and gave the following data :—

Test.	No. 1.	No. 2.	No. 3.
Sp. gr. at 15·5° C. ..	0·6865 ..	0·683 ..	0·688
B.P.	58° C. ..	64° C. ..	
50%	66° ..	66·5° ..	70% between
80%	70° ..	69° ..	60 and 80° C.
90%	72° ..	71·5° ..	
95%	76° ..	75·5° ..	
Sol. in fuming H_2SO_4 ..	4% ..	4% ..	11%

These figures show quite clearly the necessity of proving the quality before use.

It will be noted that the effect of the aromatic content of No. 3 was considerable, so it was decided to add small quantities of benzene to aromatic-free petroleum-ether, and note the result.

Mixture.	Asphalt. %
Aromatic free petroleum-ether	1·63
" " " " + 2½% benzene	1·62
" " " " + 5% "	1·42
" " " " + 7½% "	1·36
" " " " +10% "	1·26
" " " " +12% "	1·10

Having ascertained the influence exerted by the presence of aromatics, it was deemed desirable to investigate the consequences involved by the use of petroleum-ethers of other boiling-points.

The assays of these fractions were :—

Test.	B.P. under 40° C.	B.P. 40–50° C.	B.P. 50–60° C.	B.P. 60–80° C.	B.P. 80–100° C.
Sp. gr. at 15° C. ..	0·6394 ..	0·6515 ..	0·669 ..	0·683 ..	0·7097
B.P.	30° C. ..	39° C. ..	50° C. ..	64° C. ..	84° C.
50%	36° ..	44° ..	55·5° ..	66·5° ..	85·5°
80%	40° ..	50° ..	60° ..	69° ..	92°
90%	49° ..	59° ..	63° ..	71·5° ..	96°
95%	— ..	— ..	69° ..	75·5° ..	98°
Sol. in fuming H_2SO_4	1% ..	1% ..	2·5% ..	4% ..	2%

Each fraction was then freed from aromatics, and both the original and washed ethers used for determining the asphalt content.

B.P.	Original petroleum-ether. %	Washed petroleum-ether. %
Under 40° C.	2·29 ..	2 31
40–50° C.	2·12 ..	2·31
50–60° C.	1·84 ..	1·96
60–80° C.	1·67 ..	1·7
80–100° C.	1·52 ..	1·64

Although one recognises that it may be desirable to use large quantities of petroleum-ether for fuel oils, etc., it did not appear to be necessary to be quite so extravagant when working with lubricating oils. To show this, the test was conducted using 5, 10, 20 and 40 vols. The result was the same in each case, although filtration was quicker when larger volumes were used.

The usual time allowed for precipitation appears to be adequate, as no increase was found to occur, even after standing five days; nor yet was there any appreciable difference if precipitation was conducted at temperatures between 32 and 90° F.

A series of tests was then made on a large number of black oils, of which the following are representative :—

	Under 40° C. %	40–50° C. %	50–60° C. %	60–80° C. %	80–100° C. %
Black steam cylinder oil in ascending viscosity	0·30 ..	0·19 ..	0·15 ..	Nil ..	Nil
	0·39 ..	0·36 ..	0·30 ..	0·26 ..	Nil
	0·56 ..	0·51 ..	0·29 ..	Nil ..	Nil
	0·70 ..	0·70 ..	0·65 ..	0·41 ..	0·21
	2·20 ..	1·47 ..	1·05 ..	0·53 ..	0·45
Black engine oils	.. 0·08 ..	0·06 ..	0·04 ..	Nil ..	Nil
" "	0·80 ..	0·64 ..	0·45 ..	0·22 ..	Nil
" "	0·93 ..	0·70 ..	0·39 ..	0·22 ..	0·17
Fuel oil	..16·6 ..	14·6 ..	14·0 ..	10·7 ..	10·7

These results show the advantage of using petroleum-ether whose B.P. is under 40° C.; for it will be seen that there is no definite correlation between the quantities precipitated by the different fractions. All that can be said is that the amount precipitated by the higher B.P. fractions is less than that by the lower.

It has been suggested that the asphalt content can be measured by absorbing the oil in fuller's earth and extracting with petroleum-ether or solvents.

Using the same oil the following results were obtained :—

	Oil extracted. %	Oil retained by earth. %
Petroleum-ether, B.P. 60–80° C.	95·45	4·55
Carbon tetrachloride	97·25	2·75
Benzene	99·65	0·35
Ether-methylated	99·16	0·84

The oil extracted by the petroleum-ether was pale in colour, that from the other solvents being black.

The earth from the petroleum-ether extraction was next extracted with carbon tetrachloride, and 1·24 per cent. of extract obtained; as this amount was approximately that obtained by the ordinary precipitation method, the tests were repeated with each fraction of petroleum-ether as used previously.

Fraction.	Asphalt precipitation test. Insoluble in petroleum-ether. %	Extraction test. Soluble in petroleum-ether. %	Extraction test. Insoluble in petroleum-ether. Soluble in carbon tetrachloride. %
B.P. under 40° C. ..	2·29 ..	93·34	2·84
40–50° C.	2·12 ..	94·18	2·19
50–60° C.	1·84 ..	93·71	1·75
60–80° C.	1·67 ..	95·44	1·24
80–100° C.	1·52 ..	94·16	1·08

As these results seemed distinctly encouraging, a series of black oils was undertaken, but as the following figures show, the method proved quite unreliable.

B.P. of Fractions.	Asphalt precipitation test. %	Soluble in petroleum-ether. %	Soluble in carbon tetrachloride but insoluble in petroleum-ether. %	Soluble in benzene but insoluble in petroleum-ether and carbon tetrachloride. %	Oil retained by earth. %
Black engine oil—					
Under 40° C. ..	0·8 ..	90·17 ..	1·40 ..	1·74 ..	6·69
40–50° C. ..	0·64 ..	89·0 ..	3·44 ..	1·68 ..	5·98
50–60° C. ..	0·45 ..	92·46 ..	4·46 ..	0·82 ..	2·26
60–80° C. ..	0·22 ..	90·49 ..	1·83 ..	0·75 ..	6·93
80–100° C. ..	— ..	95·82 ..	0·95 ..	0·75 ..	2·48

Black steam cylinder oil—										
Under 40° C.	..	0·3	..	95·5	..	1·92	..	0·19	..	2·39
40–50° C.	..	0·19	..	95·97	..	1·85	..	0·28	..	1·90
50–60° C.	..	0·15	..	96·41	..	2·25	..	0·93	..	0·41
60–80° C.	..	Nil	..	95·06	..	1·95	..	0·60	..	2·39
80–100° C.	..	Nil	..	96·25	..	0·94	..	0·33	..	2·48
Black steam cylinder oil—										
Under 40° C.	..	0·39	..	89·18	..	6·76	..	1·72	..	2·34
40–50° C.	..	0·36	..	93·77	..	3·97	..	2·04	..	0·23
50–60° C.	..	0·30	..	97·40	..	1·64	..	1·93	..	0·03
60–80° C.	..	0·26	..	96·03	..	1·24	..	2·48	..	0·25
80–100° C.	..	Nil	..	96·18	..	1·13	..	2·44	..	0·25
Black steam cylinder oil—										
Under 40° C.	..	0·56	..	92·47	..	3·03	..	1·09	..	3·41
40–50° C.	..	0·51	..	93·82	..	3·06	..	0·46	..	2·66
50–60° C.	..	0·29	..	94·72	..	2·80	..	0·47	..	2·01
60–80° C.	..	Nil	..	97·13	..	0·85	..	0·24	..	1·78
80–100° C.	..	Nil	..	93·25	..	1·02	..	0·56	..	5·17
Black steam cylinder oil—										
Under 40° C.	..	0·7	..	95·73	..	3·21	..	0·69	..	0·37
40–50° C.	..	0·7	..	93·16	..	2·90	..	0·90	..	3·04
50–60° C.	..	0·65	..	96·70	..	2·21	..	1·22	..	—
60–80° C.	..	0·41	..	93·33	..	2·26	..	0·69	..	3·72
80–100° C.	..	0·21	..	94·86	..	0·70	..	1·14	..	3·30
Pale cylinder oil—										
Under 40° C.	..	Nil	..	97·77	..	1·45	..	0·25	..	0·53
40–50° C.	..	Nil	..	98·64	..	1·08	..	0·27	..	0·01
50–60° C.	..	Nil	..	97·54	..	0·28	..	0·27	..	1·91
60–80° C.	..	Nil	..	97·73	..	0·39	..	0·24	..	1·64
80–100° C.	..	Nil	..	99·23	..	0·49	..	0·33	..	—

My thanks are due to Messrs. C. C. Wakefield and Co., Ltd., for permission to publish these results, and to Mr. W. D. Doughty, A.I.C., who conducted most of the tests.

Psycho-Galvanic Measurement of Smell.

By Lt.-Col. S. J. M. Auld, O.B.E., M.C., D.Sc.

Shortly before his death Professor A. D. Waller, of the University of London Physiological Laboratories, developed a method of measuring nervous emotion in terms of conductance at the surface of the skin. Some of his results were published in scientific journals (*e.g.*, Bull. Ac. Roy. Med., Belg., 1919), but the method as a whole could not be applied quantitatively for any but particular cases.

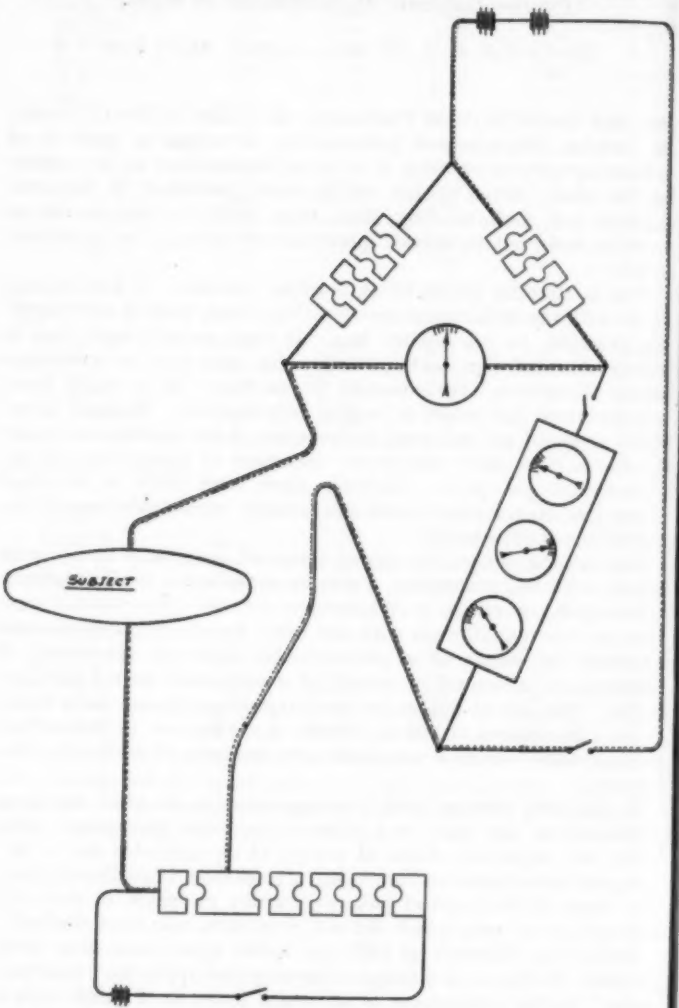
The mechanism of the effect is rather obscure. It has nothing to do with the well-known transpiration effects such as are known, for example, to accompany fear. It runs parallel with, but is independent of, the lachrymatory and sudoriparous excretions which themselves are indicative of emotion. It is much more sensitive and the effect is largely subconscious. Waller's hypothesis assumed an emotional disturbance of the equilibrium of the trophic nerves, with consequent distention or contraction of the ultramicroscopic pores overlying them and with a resultant alteration of corporeal resistance readily observable under the conditions of experiment.

The apparatus used (see figure) consisted essentially of two cells which, with two resistances, a galvanometer and a third resistance constituted, in effect, a Wheatstone Bridge. The subject was brought into equilibrium with the other resistances, sensitiveness adjusted by means of a potentiometer and the alterations of conductance measured by means of a calibrated mirror galvanometer. The actual figures for the subject's resistance were found to vary from about 50,000 to 100,000 ohms, but are, in themselves, unimportant. Contact was made with the palm of the hand or the forearm.

It was very striking with this apparatus to see one's emotions registered on the scale or rendered permanent photographically. Thus, the registered effects of receipt of an agreeable and a disagreeable letter could amount to an increase from 15 to 25 gemmhos. The effect of the slightest pain, *e.g.*, a tiny pin-prick, or even the anticipation of pain which did not eventuate, was most marked.

During the Summer of 1921 the writer spent some time with Professor Waller in an attempt to develop and apply the "emotion-meter" to the obtainment of an actual measure of smell, with a view ultimately to getting a permanent and possibly quantitative record of the odours of various substances. The underlying idea

was the possibility of comparing in actual figures the odours of new petroleum products with those of others already on the market.



It may be said at once that the attempt was unsuccessful; but the process is very fascinating and the eventual possibilities of its

application appear so wide that this note has been presented, and written up more fully than its immediate negative value would warrant, in the belief that others will find it both stimulating and suggestive.

A number of preliminary experiments were carried out with three separate observers. Subjects vary considerably in their degree of sensitiveness and were classed by Waller as sub-sensitive, normal, and super-sensitive. It happened that amongst the three observers all classes were represented.

When attention was turned to the question of discriminating between pleasant and unpleasant smells, very marked effects were obtained with the merest traces of chloropicrin as representing the worst possible, but the slight differences appertaining to the series of petroleum products which was tried out, were difficult of detection. All three observers reacted strikingly to alternate whiffs of untreated benzine, " A," on one hand, and fully refined petrol, " B," from the same source, and two other refined petrols, on the other ; but no distinguishing reaction between the last named three could be measured, either amongst themselves, or in comparison with chemically pure hexane or cyclohexane. On the other hand one observer showed a slight, but distinct, preference for the fully refined petrol " B " as against a spirit containing appreciable amounts of cracked compounds.

When the apparatus was rendered more sensitive in attempts to detect slight preferences of smell, outside influences became so marked as to make the method useless. It would possibly only be satisfactory if the observer could be emotionally insulated and rendered bodily inert.

In any case it must be remembered that even if otherwise successful the observations would only represent the personal reactions of the individual. Still, even that would be most useful if it were possible to eliminate outside influences altogether.

The conclusion was come to that the whole process was too much in embryo to merit immediate industrial prosecution, but the experiments gave a fillip to the writer's ideas on the subject of smell measurement and should be of interest to others to whom Waller's work may be unknown.

REVIEWS.

REDWOOD AND EASTLAKE'S PETROLEUM TECHNOLOGISTS' POCKET BOOK. Second Edition, 1923, revised by Arthur W. Eastlake. Pp. 546+xxiv., 41 figs., 8 maps. London: C. Griffin and Co. 15s. net.

Mr. Arthur W. Eastlake and his collaborators have undertaken an ambitious enterprise in preparing this second and greatly enlarged edition of the reference book produced by Sir Boverton Redwood and Mr. Eastlake.

Petroleum technology has probably more ramifications—geological, geographical, physical, chemical and engineering—than any other branch of technical science, and all those whose activities are connected with any section of the subject know only too well how frequently thay have need to refer to technical data belonging to one of these cognate branches of science.

Most scientific pocket books fail in their true purpose by attempting to be text-books when their one function should be to present a complete and well-arranged grouping of data and information. We are pleased to see, therefore, that in this work the Testing section occupies six pages only.

The scope of the book is best indicated by the heads under which this great quantity of valuable information has been classified, and we must again emphasize what a remarkably complete compilation of data and tables accompanied, where necessary, by excellently produced diagrams this compact reference book contains. In particular, analyses of an extremely large number of crude oils, natural gases and shales are included. The arrangement is as follows:—

Part I.—General Information. 56 *pages.*

Prospecting, field equipment and laws relating to the leasing of properties in various countries.

Part II.—Geological. 32 *pages.*

Part III.—Physical and Chemical. 132 *pages.*

Analyses of a wide range of gases, crude petroleums and asphalts, including calorific values, specific heats and other useful data and many conversion tables. This section has been revised by Professor Brame, and is one of the best in the book.

Part IV.—Production. 57 *pages.*

A short but excellent summary of the technique of drilling, maintaining and controlling oil and gas wells.

Part V.—Refining, Transport, Storage and Testing. 25 *pages.*

This section deals principally with storage and transport—*i.e.*, with tanks and pipelines. Considering the importance of this branch the section seems inadequate; it is the only disappointing section of the book.

Part VI.—Uses. 38 *pages.*

This section, though short, contains a great deal of valuable information regarding gas, fuel oil and asphalt; other petroleum products such as petrol, kerosene and lubricating oils are dealt with very briefly—perhaps too briefly in view of their importance, while Diesel oil is barely referred to.

Part VII.—Weights and Measures. 49 *pages.*

Mainly conversion tables.

Part VIII.—Miscellaneous. 68 *pages.*

This part contains some useful information, especially a list of the papers read before the Institution of Petroleum Technologists. Other sections comprise details of the Petroleum Courses at London, Birmingham, Manchester and Colorado Universities, a summary of the principal English and American text-books on petroleum, a dictionary of abbreviations and various geographical, legal and financial statistics. Some of the material in this part seems rather superfluous, and we would have liked to see Parts V. and VI. expanded at the expense of Part VIII.

Part IX.—Statistics. 50 *pages.*

Production of petroleum products in various countries during the past twelve years.

The book is very thoroughly indexed and well bound, and can be recommended as a most valuable addition to the reference libraries of all connected with the petroleum industry. F. B. T.

"Petroleum Resources of the World." By Valentin R. Garfias. Pp. 237. New York: John Wiley and Sons. London: Chapman and Hall. 15s. net.

Mr. Garfias' book fairly fulfils the author's intention as expressed in the preface. It is "a concise record of salient facts related to the producing and prospective oil-fields of the world." A book of this kind obviously does not supersede the larger works of reference, but has its value away from technical libraries, as a supplementary volume to such books as Ziegler's *Oil Geology*, and Andros' Handbook in America, or Redwood and Eastlake's Handbook in England. The book is mainly for persons already acquainted with elementary oil facts, and the author assumes that his reader knows the distinction between "standard" and "rotary" drilling, and he does not think it necessary to append any cautionary remarks to his useful table of "Physical and Refining Properties of Petroleum," *e.g.*, to point out that in commercial practice the products obtained and marketed from a given crude oil may differ from time to time very considerably from the potentialities which the chemist may discover in the laboratory.

An Englishman using this book will think, perhaps, that some of the geographical and political details given in regard to well-known countries might have been abbreviated to make room for additional oil data. Obviously, however, where changes of boundaries and names of countries have taken place, a mention of such facts is useful. The author has taken considerable pains to bring his facts up to date, but petroleum statistics, legislation, and prospecting, is ever progressive, and it is possible, therefore, to point to some instances where later information is already available. At random, we note that no mention is made of drilling work carried out by more than one company in Croatia, and only incidentally is allusion made to similar work in Hungary. We think also that storage in Rumania, and petroleum legislation in that country, have moved on somewhat since Mr. Garfias collected his data.

The maps used in the book are generally of a useful character, but the map of the world's oil-bunkering stations is on too small a scale to be of practical use. Whilst we think that Mr. Garfias might have assumed that his readers would be acquainted with the fact that "the Dominion of Canada lies north of the United States," he expects a very detailed geographical knowledge on their part to fill in the names of bunkering ports, represented by a number of small black dots scattered over the world. F. W. B.

"Oil Flow—Viscosity and Heat Transfer." R. S. Danforth. Pp. 16. 15 diagrams.

This little handbook is a companion to the author's *Oil Flow in Pipe Lines*. It consists essentially of a number of viscosity-temperature curves for various American Fuel Oils, and curves connecting the diameters and mean temperatures of pipe lines with the temperature drop and pressure-loss for oils of various viscosities and initial temperatures. Provision is made in these diagrams for variation in the heat transmission coefficient due to the degree of insulation of the pipes and for the effect of turbulent flow.

The curves have been constructed from data supplied from reputable sources and should be of considerable value to those engaged in the transport of oil by pipe line. F. B. T.

"The Examination of Petroleum." Hamor and Padgett. McGraw-Hill Book Company. 591 + viii. pp.

Petroleum technologists who were already familiar with that excellent treatise by Bacon and Hamor on *The American Petroleum Industry* must have enthusiastically welcomed the promise of a laboratory companion to this by an author whose ability was already so well proved.

The anticipations have been fully justified; the present volume, though more limited in its scope than Holde's well-known work in that it deals solely with mineral oil, is all, and its Appendix much more, than we hoped for.

The book is divided into two practically equal portions. The first consists of ten chapters dealing in ample detail with the methods in use for testing crude petroleum and its various distillation products, bituminous road materials, oil shale and natural gas and in addition we have an excellent chapter by F. W. Sperr of the Koppers Company on benzol recovery plant and its products.

The majority of the tests described are those standardised by the A.S.T.M.; others which have not yet received this hall-mark but which have been approved by competent authorities are also included.

The authors deserve special thanks for supplying information which, though of great assistance to the analyst, is only too rarely offered in analytical treatises—namely, the limiting results which experience has shown to be desirable for each product. It is in this connection that the second and, to many of its users, the more valuable half of the book, the Appendix, is so extraordinarily helpful. This appendix, besides containing a few essential conversion tables such as Baumé degrees to Specific Gravity and Saybolt Viscosities and Colours to English units, contains nearly 300 pages in small print of typical specifications issued by the greatest American consumers for practically every petroleum product. A large number of the well-known Bureau of Standards Circulars dealing with suitable methods of testing and the appropriate apparatus are also quoted. There are remarkably few errors of commission and of omission. We greatly regret that the "loss to sulphuric acid" is still alleged to give an approximate indication of the content of unsaturated hydrocarbons, though reference is made to that important investigation by Brooks and Humphrey which so effectively disproved this assumption.

A serious omission is that of a method for the determination of aromatic hydrocarbons in gasoline, though references are made in footnotes to various proposed methods. Now that an approved method has been issued by the British Engineering Standards Association after careful test, we may hope that in the next edition the chapter on gasoline will not lack detailed description of a procedure which is becoming one of the most important in the analysis of motor fuel. F. B. T.

"The Genesis of Petroleum." By P. E. Spielmann. Ernest Benn, Ltd. 72 pp.

It has been credibly asserted that when petroleum technologists feel in an argumentative mood they mention their views on the origin of petroleum, and a vigorous discussion then continues till circumstances intervene and a strictly temporary armistice is proclaimed. Dr. Spielmann has been sufficiently cautious to refrain from putting forward his personal views, but he evidently possesses a very complete card index of published papers on this subject, which he has summarised in a thorough, well-classified and readable manner, and coupled with an up-to-date bibliography. The modern theories, inorganic, vegetable, and animal, are briefly outlined, and the two latter, which alone withstand even superficial criticism, are then considered critically in the light firstly of the chemical composition of petroleum, and secondly of laboratory attempts to prepare products resembling petroleum. It is regrettable, though hardly surprising, that the latter appear to be entirely unconvincing. Though many investigators have stated that a particular reaction has yielded "a product closely resembling petroleum," no chemical evidence ever seems to be put forward identifying the individual components with those present in any of the widely differing materials known as "petroleum," and the resemblance appears to be solely in the fact that these "synthetic petroleums" are dark coloured, float on water and are combustible. A further instance of looseness of expression is the statement, of which even Dr. Spielman is guilty, that some petroleums contain nickel, which is under certain circumstances known to possess catalytic activity. We know no petroleum which contains nickel, though some contain compounds of nickel—a very different thing from the catalytic standpoint.

Space and the argumentative tendencies of the subject forbid detailed criticism, but we would have liked more than three lines of reference to the possible mode of formation of aromatic hydrocarbons. Putrefaction of protein matter containing tyrosine nuclei is quite inadequate, and the writer would suggest as more probable the dehydrogenation of cyclohexane derivatives, an operation which can be accomplished in the laboratory with ease, even below 300° C. Dr. Spielmann's summary of published work on this question is a most effective stimulant to thought, and discussion, and can be strongly recommended.

F. B. T.

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